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TRANSACTIONS

OF

THE CERAMIC SOCIETY

INCLUDING

THE REFRACTORY MATERIALS SECTION.

Founded in 1900 as "The North Staffordshire Ceramic Society,"
and continued from 1903 to 1916 as
"The English Ceramic Society."

VOLUME XXII.—SESSION 1922-23.

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REFRACTORY MATERIALS SECTION

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RULES.

(Subject to modification by recommendations from the Refractory Materials Section).

1.—The Society shall be called THE CERAMIC SOCIETY. It shall comprise a special section dealing with Refractory Materials.

2.—The object of the Society shall be the discussion of all subjects relating to the industries connected with Clay Working and Refractory Materials.

3.—Persons desirous of membership shall be proposed and seconded by two Members of the General Meeting, and they are then eligible for election at the next Council Meeting.

4.—The Society shall be governed by a President, Past-Presidents, Vice-Presidents, a Council, a Librarian, a Secretary, and a Treasurer. The President shall be elected in alternate years by the Pottery Section and by the Refractory Materials Section, and shall, upon the expiration of his year of office, become Chairman of his own Section for the ensuing year. The Office of Past-President shall be held by retiring Presidents. The Pottery Section, and the Refractory Materials Section, shall each elect three Vice-Presidents, one of whom shall retire annually, and shall not be eligible for re-election until after the lapse of one year. Other Officers shall be elected at the last General Meeting of each Session, and shall hold office until the last General Meeting of the ensuing Session, when they shall be eligible for re-election. A Chairman of Council shall be appointed by the Council.

4a.—The Council shall consist of officers, Past-Presidents, Vice-Presidents and twelve members, of whom four shall resign each year, the retiring members to be eligible for re-election.

4b.—Two additional members of the Council, one of whom will also act on the Publication Committee, shall be elected by the Federation of Pottery Manufacturers.

5.—The headquarters of the Society shall be the Central School of Science and Technology, Stoke-on-Trent.

6.—The Meetings shall be fixed from time to time as arranged by the Sectional Committees. At Stoke-on-Trent the Meetings during the Session are usually held at 7-30 p.m. on the second Monday of the month.

7.—The annual subscription shall be payable in advance, and shall be fixed from time to time by the Committee (25/- for 1922-23). Members of the Society who have paid their annual subscription receive a copy of the TRANSACTIONS free.

8.—A firm can join the Society by paying an annual subscription of two guineas. For this subscription the attendance at each meeting shall be limited to three members of the firm, and one copy of the TRANSACTIONS will be supplied free annually.

9.—New members shall pay an entrance fee of one guinea.

10.—Students may be elected to Student Memberships without paying an entrance fee. Their subscription shall be 5/-, and will entitle them to attend the meetings, but no TRANSACTIONS will be supplied. After twelve months membership, a Student can be elected to full membership without payment of entrance fee. The Council shall decide whether a person is eligible for a Student Membership.

11.—Notification of meetings shall be sent by post to each member in Great Britain with the name of the subject of the paper for discussion.

12.—In the discussions arising upon any paper, no speaker shall occupy more than ten minutes, or make more than one speech, except by the permission of the Chairman.

RULES—*Continued.*

13.—Any property of the Society lent to members must be returned within a week.

14.—Any member promising a paper and failing to keep his appointment shall himself provide a substitute.

15.—The Society shall have the prior right of publication of all papers read before it for a period of three months.

16.—Authors must send their papers to the Society before or immediately after the communication has been read. If received in time the paper may be printed in time for the meeting. The official receipt of any paper will be dated from the time it is received by the Secretary.

17.—Members may obtain one copy of each of the back numbers of the TRANSACTIONS at subscription rates, providing they are for their own personal use, and that the number in stock be over 18.

18.—Members who are three years in arrear with their subscriptions shall be informed by means of a printed notice, and if the arrears are not paid within a month their names shall be struck off the list. *New Members are put on the list of members when their subscriptions have been paid.*

19.—A member of the Society may introduce a visitor to an ordinary meeting. A visitors' book is kept to show what non-members are present, and by whom they are introduced. The names of the visitors are read out by the Chairman at the opening of the same meeting.

20.—No alteration or addition to the above Rules shall be made except notice be given in General Meeting, and passed by the ensuing General Meeting. Ten to form a quorum.

The Scandinavian Tour, 1922.

By H. Townsend.

WHEN the Ceramic Society returned from France a year ago, after a most interesting and enjoyable tour of Alsace and Lorraine, it was genuinely felt that the high-water mark had been reached in connection with the Society's tours, which, from the commencement, have clearly been progressive in their scope and character. The trip to Sweden and Denmark, however, will doubtless be considered by those who took part, to have surpassed, in many respects, all its predecessors. The receptions accorded in both countries by a host of friends and sympathisers, all of whom seem to have regarded the visits as an honour and sheer delight, were hearty in the extreme. If hospitality counts, anything more advanced than we have just experienced in Sweden and Denmark would be unsettling, if not dangerous.

The tour commenced on Saturday, May 27, when a party numbering close upon fifty left St. Pancras Station for Tilbury Dock, and embarked there at midday on the s.s. "Saga" for Gothenburg. The company was made up of well-known manufacturers of fine earthenware and china, as well as producers of fireclay bricks and refractory materials, oven experts, pottery chemists and consultants, and others interested in the production of pottery from one or another angle. There were also five ladies. The list of those who participated is as follows :—Dr. J. W. Mellor, of the Stoke Pottery Laboratory, Mr. H. E. Wood (President), Sir Wm. J. Jones, K.B.E. (Past President), Mr. H. J. C. Johnston (President of the Institute of Clayworkers), Mr. A. Stuart Johnson, Mr. R. L. Johnson, Mr. A. Fielding, Mr. Tom Hammersley, Mr. H. J. Plant, Mr. S. Hawthorne, Mr. E. D. M. Scrivener, Mr. J. Steventon, Mr. R. G. Harris, Mr. W. Lindley, Mr. W. S. Lindley, Mr. W. G. Fox, Mr. W. M. Bakewell, Mr. A. Harrison, Mr. B. C. Harrison, Mr. H. T. Arrowsmith, Miss G. Hulme, Mr. and Mrs. J. Williamson, Mr. and Mrs. Parker MacKinlay (New Zealand), Mr. B. Ivers (India), Mr. J. Holland (Sheffield), Mr. W. J. Gardner (Meltham), Mr. F. H. Brooke (Oughtibridge), Mr. T. Wragg (Swadlincote), Mr. A. H. Middleton (Consett), Mr. W. Hamilton (Glasgow), Mr. G. A. Hodson (Hathern, Nr. Loughborough), Mr. A. E. Carder and Mr. A. H. Carder (Brierley Hill), Mr. and Mrs. C. S. Spiers (London), Mr. C. H. Moore (Sheffield), Dr. H. G. Colman (London), Dr. W. L. Freeman (Bristol), Mr. and Mrs. Herford Hope (Colchester), Mr. W. T. Gardner (London), Mr. W. Hitchen (Stockport), and Mr. H. Townsend.

"Every Silver-lining has a Cloud."

"The Cloud."

A 44-hour sail brought the party to Gothenburg, where they were met on arrival by Mr. A. S. W. Odelberg, of the Gustafsberg Pottery, near Stockholm, who has long been a member of the Ceramic Society, and who, for some months past, has played a very active part in the organisation of the tour. As the result of a telegram which had been received from the Swedish Foreign Office, all unnecessary formality in connection with the verification of passports and the examination of baggage was obviated, and almost immediately upon landing the party seemed to enjoy the full freedom of the country. Rooms at the Grand Hotel, Gothenburg, had been provided for the day, and no sooner had the hotel been reached than a number of local pressmen were hard at work with their cameras, with the result that within a couple of hours of the arrival of the "Saga" at the quay a group photograph of the party was appearing in the Gothenburg morning newspaper, with a series of special interviews with such distinguished visitors as Dr. Mellor, Sir Wm. Jones, and others. This was followed up in later editions of the newspaper in question by a series of pen-and-ink caricatures of several members of the party, which, if not faithful likenesses, were not lacking in a sense of humour. It occurred to one that, although the pictorial work of the Swedish newspapers is somewhat behind that of the English Press, the speed at which the Swedish Press gets to work is distinctly creditable.

The visitors also lost no time in settling to work, for within an hour of the arrival at Gothenburg a visit was being paid to a pottery there, known as the "Goteborgs Porslinsfabrik," which manufactures a wide variety of earthenware for domestic uses. The party was received by the principal, Mr. Simeon Swartz, and Mr. Edwards (Technical Manager), who conducted them round the establishment. The factory in question is equipped very much on the lines of an English earthenware manufactory, and produces one type of body only—a white earthenware, of a somewhat soft texture. From what one could gather, ivory ware is of little or no interest to the people of Sweden. Three hundred hands are employed at the present time, although there is accommodation for twice that number, since the factory was largely extended during the war, when the Swedish potters were supplying practically the whole of Norway with domestic pottery. Since the war, the export trade has apparently fallen away very considerably, the rate of exchange being the chief adverse factor. One learned that the factory in its modernised state is capable of turning out about twelve glost ovens per week, but that only half that number are being drawn at present for the reasons stated.

The Gothenburg pottery is well equipped with machinery, and Mr. Swartz, in conversation with the writer, seemed very proud to announce the fact that practically the whole of the plant in the factory was supplied by a Staffordshire house—William Boulton, Ltd., of Burslem. We noticed, however, that in addition

thereto, there was a row of seven or eight huge electrically-driven cylinder grinders, supplied by Rohrbach, in the sliphouse. All the power for the factory, by the way, is electrical, the current being drawn from the power-station at Trollhattan, some sixty miles distant. The current is generated at the waterfalls at about 20,000 volts; it is transformed down to 6,000 volts *en route*, and is delivered at the Gothenburg factory at that voltage; it is then again transformed down to 240 volts, at which it is used. The sliphouse arrangements of the factory are of the normal type, the materials employed being Dorset ball clay, Cornish china clay, and the ordinary French flints. Both pug mills and roller mills are employed in the sliphouse, both types being supplied by the Staffordshire firm of potters' engineers already mentioned.

There was nothing to be seen in the making shops that was vastly different from the ordinary English practice. In the glazing of the ware, however, it was noticed that a fritted lead glaze was being employed, and it was interesting to hear that the firm has never yet had a single case of lead poisoning, although the factory is now twenty years old. We were unable to ascertain in the short time at our disposal as to whether the Swedish factory regulations are as stringent as those in force in England, although we did succeed in eliciting the information that the starting age of juveniles is fourteen years, and that before commencing work in the pottery a certificate of school attendances, as well as of health, has to be presented to the prospective employer. We also learned that it is not obligatory upon the manufacturer to supply free milk to his lead-workers. At the same time, we observed that there were quite a number of workshop practices in force, having for their object the promotion of hygiene. Every woman worker, for instance, was supplied with overalls, which are provided by the proprietors. In this matter the firm has apparently anticipated possible factory regulations. It was also noticed that every workshop is equipped with a series of dust-proof lockers, in which each worker can deposit his or her outdoor garments on settling down to work in the factory.

The saggar house of the Gothenburg pottery proved interesting, and it was observed that die presses operated by hand are used for the construction of the round saggars, even up to large sizes. It has often been said in England that this method is unsatisfactory, but it appeared to be giving no trouble in Gothenburg. The saggars were said to be capable of sustaining fifteen firings, on the average, for both biscuit and glost oven placing. The saggar clay employed is drawn from Höganas, in the south of Sweden, and is mixed with grog, also purchased at the same place.

In passing through the decorating shops it was observed that the Gothenburg pottery is strong on prints and stencilled decorations in both of which classes the productions remind one forcibly of those of Villeroy & Boch, at Mettlach, which factory was visited

by the Society a year ago. The printing was all done by hand presses, as in England. A particularly strong line of the productions of the house was seen to consist of decorations which are either simply stencilled, or stencilled and aerographed. The body being rather soft, the stencils are easily applied, and the decorations show up with quite good effect. The ornaments are simple, and for the most part regularly applied to the ware at intervals. In dinnerware, for instance, we noticed that one of the most popular patterns had simply three bunches of stencilling arranged at set distances, these being connected up by lining off in the centre of the rim. Everything is produced by the firm in domestic ware, from white tea and dinnerware, through ornamental ware in much variety, up to huge pieces of sanitary ware. The output of the factory is extremely cosmopolitan in type.

One could not help forming the impression that the Gothenburg pottery is very favourably placed for the reception of raw materials, bearing in mind that all these have to be imported. The ships from Gothenburg leave for England loaded with timber, and come back from England loaded with raw materials as ballast. Again, the factory is abundantly blessed with cheap power, since the price for electrical current is not more than £3 per year per h.p., with no limit to the consumption. Labour was said to be expensive, although it was stated that the average price for skilled woman labour was about 60 ore per hour—equal to about 7d. or 8d. in English money—and for skilled male labour about double that amount. In spite of all this, however, the factory at the present time is only working at about half its maximum, and is therefore in no better position commercially than are the English manufacturers working under much heavier all-round expenses.

After having partaken of lunch at the Grand Hotel, a visit was paid to the wonderful S.K.F. ball bearing factory, which everyone considered to be a unique example of rapid industrial growth. One of the principals, Mr. Helmstein, explained to the visitors, who first of all congregated in the company's palatial offices, that fifteen years ago, when the factory was founded, it employed only twelve workmen, but after ten years' run, with considerable extensions to the factory, the number of employees in Gothenburg was about 4,000. In the meantime, the concern had established a number of factories abroad, particularly in England, France, and America, each one of these having a considerable productive capacity. When the factory in Gothenburg is running on full time it can make 20,000 ball bearings and one million balls of average sizes daily. At the present time the concern has ten factories in operation, with ninety-nine branches all over the world. The advantages of ball and roller bearings in different industries were emphasised by Mr. Helmstein, who cited instances where factories had scrapped all their plain bearings and installed ball bearings, thus making an annual saving of about 30 per cent.

in power, whilst also giving better results. With regard to the pottery trade, whilst the company had not yet had the advantage of any lengthy experience, it was quite evident that the advantages of ball and roller bearings could be rationally utilised. For instance, a large pottery works at Helsingfors, to wit, the Arabia Porlinsfabrik, was now equipped throughout with ball and roller bearings. The line shaftings, as well as the machines of different kinds employed, were all running in these bearings, including, amongst other appliances, a couple of large tube mills. The directors of the factory had commissioned an engineering firm in Helsingfors to investigate the saving in power accomplished by the ball bearings, and according to a certificate drawn up, the saving amounted to 12 per cent. The Gafle Porslinsfabrik in Sweden had also had tube mills running successfully on ball bearings for some years.

At the conclusion of this address, Mr. A. Fielding inquired what effect a dusty atmosphere would have upon ball bearings of the type demonstrated. This question having been satisfactorily answered by Mr. Helmstein, Sir William Jones thanked the principals for the permission to see the works. He said that all present must, of necessity, be interested in the problem of anti-friction bearings, since the economies which had been referred to in connection with running costs, as well as the elimination of fire risks, were not difficult to grasp.

In going round the S.K.F. factory it was noticed with regret that, owing to the falling off in trade, as the result of the depression in the engineering industries of the world, instead of 4,000 workers being in employment, only 300 were at work to-day on specialities. The factory is remarkably well equipped, and everyone was delighted to have the opportunity of seeing its wonderful plant.

A unique reception was met with the same afternoon in the "Palace Grounds" at Gothenburg, where the Anglo-Swedish Society had provided a charming tea, which was served by a number of Swedish girls dressed in brilliant national costumes, a local regimental band playing selections throughout. The Governor of the city, His Excellency Oscar von Sydow (late Prime Minister of Sweden), was present, accompanied by Mrs. von Sydow, and was supported by a distinguished gathering of Gothenburg citizens. Mr. George Dickson, the chairman of the Anglo-Swedish Society, and, incidentally, also the chairman of one of the largest Swedish banks, welcomed the visitors to the ancient land of the Vikings. He outlined the antiquity of Gothenburg and its amenities, expressing the view that in no place in Sweden would Englishmen find more to interest them than in Gothenburg. Time after time Englishmen had settled there, and had done much to improve the commercial prosperity of the city, whilst at the same time making a mark for themselves. Many of the social and philanthropic institutions of the town were the result of English bequests. The visitors would, before their return, pass through some of the most

lovely parts of Sweden; they would see its beautiful waterfalls, its forests, its industrial enterprises, and its lovely capital. In the course of this journey it would be found that the Swedes sympathised with the English, and that the sympathies would be reciprocal he did not doubt, for the Scandinavian and English races were bound by kindred ties.

The welcome was further emphasised by Mr. C. H. R. Baldwin, the founder of the Anglo-Swedish Society, and H.M. Vice-Consul at Gothenburg, who made reference to the good work that the Society is doing in the maintenance of good relationships between Sweden and England. Its idea was to promote a closer and more intimate relationship between the two countries. The work of the Society was, he said, also to a great extent educational. The rooms of the Society were open to Englishmen at all times free of charge; they contained an English library, and consistently provided a number of English daily and weekly newspapers, which could always be consulted by English people passing through Gothenburg. It was the aim of the Society to appeal to the citizens of both countries. An intense propaganda was being carried on both in Sweden and England, and the development was being felt. The Society boasted of about 1,400 members in Gothenburg alone.

Sir William Jones, on behalf of the Ceramic Society, returned thanks for the welcome, and the function was brought to a close by the calling of "four hurrahs" for the English, which was responded to by the visitors with three cheers and musical honours.

A dinner was held the same evening in the "Tradgardsforeningen"—a beautiful open-air restaurant in the Botanical Gardens. The first speaker was Mr. A. S. W. Odelberg, who expressed his delight at the visit of the English Ceramic Society to his beloved country. He recalled the fact that it was in 1914, when the Society was returning from Limoges to Paris, in a corridor coach of a shaking train, that there was some mention of a little country called Sweden. "That is *my* country," he had said. "Would you like to pay it a visit?" And so it was arranged, and the year 1916 decided upon. But the war cloud burst in the meantime, and the visit had to be abandoned. There was, however, a proverb in Sweden that, if one waited for something really good, one never had to wait for long. What he had been hoping for for six years, was now an accomplished fact. "My friends, you are here," said Mr. Odelberg, "and you have not only brought your good English humour, which I always love so much, but you have brought also most beautiful weather. We have had a long winter here, but now we have the spring, whilst you in England are enjoying the summer." Mr. Odelberg went on to say that he was proud to be able to show the visitors what was being done in the country of his birth. They had seen that day what was being done in regard to the production of pottery: they had also been able to see the precision work that was being accomplished in a wonderful engineering works. He hoped

they would also, in the course of their wanderings during the next fourteen days, be able to see that Swedish organisation can be precise in other matters, and that the arrangements which have been made for the tour would in no detail break down. He raised his glass to his English friends of the Ceramic Society, to which he was proud to belong. The Society was two years old when he joined it ; it was now twenty-one, ripe in age and full in vigour.

Sir William Jones responded. He said he was convinced that the first day that he had spent in Sweden was a happy augury of the days that were to come. On behalf of his fellow-travellers, he tendered his sincerest thanks for the excellent arrangements which had been made by Mr. Odelberg and others for the tour. Sir William added that he had learned that evening that Mr. Odelberg's son had passed successfully, and with distinction, an examination which might have an important bearing upon his future career. He hoped that that success might be carried forward from strength to strength, and that Mr. Thorsten Odelberg would prove a worthy successor to his remarkable father.

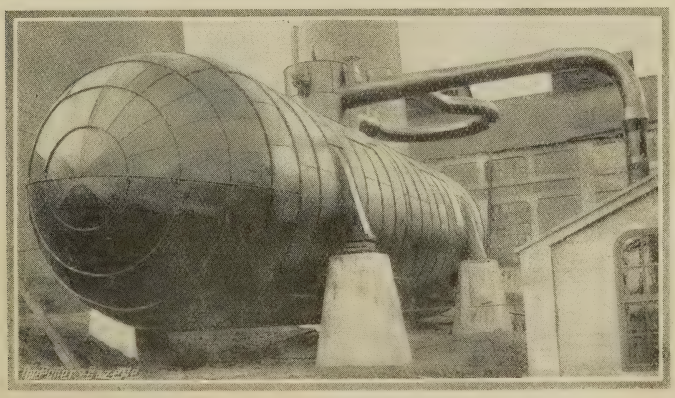
Mr. H. J. C. Johnston, the President of the Clayworkers' Institute, proposed the health of Mr. Woodhouse, H.M. Consul, and that gentleman, in his response, expressed the view that Sweden was offering the visitors its heartiest form of welcome. He regretted that the factories they were to visit, which were equipped for business in a marvellous way, were feeling the effects of the depression that was world-wide, and he sincerely trusted that, before long, not only the Swedish but the English factories also would be in full swing. He was sure that Sweden was worth a good deal more attention than Britishers were prone to pay to her. Sweden was worth cultivating, and he hoped that the visitors would take home with them a really good impression of the country. He raised his glass to "Sweden and her representatives present."

Mr. Baldwin, H.M. Vice-Consul, also spoke, remarking that he had lived in Sweden for seven or eight years, during the good days and the bad, and he had acquired an enthusiasm for Sweden. He referred to the fact that next year there is to be an important exhibition in Gothenburg, and he hoped it would be well patronised by the British people. He asked all present to rise and drink to "Anglo-Swedish relationships." The respective toasts were received with enthusiasm, and a remarkably happy gathering was brought to a close at a late hour.

At their leisure, the party retired to the sleeping cars of a special train which was standing in the Bergslagens station, and during the night travelled on to Trollhattan, known as the "Niagara of Sweden"—a place well known for its magnificent scenery, and of considerable importance to Swedish industrialists because of the fact that the water has been harnessed there in order to provide electrical current for the industries of many distant towns. Immediately following breakfast, which was provided at the Trollhattan

Hotel, the party adjourned to a lecture-room next door, where Director Sylvan, the chief of the Government Power Station at Trollhattan, gave a most interesting sketch of the electrical undertakings at the Trollhattan plant. The Trollhattan Falls are over 100 ft. high, and the volume of water ranges from 320-900 cubic metres a second. At the present time about 170,000 h.p. are utilised. After the lecture, a visit was paid to the waterfalls and the power station, and thus a splendid opportunity was provided of forming lasting impressions of the wonderful scenery hereabouts, and of the bountiful way in which nature has endowed Sweden with sources of energy capable of being won and made use of in the furtherance of industry. After lunch a visit was paid to an engineering works engaged in the construction of locomotives for Russia, and afterwards a short sail was taken up the lake above Trollhattan to a graphite works, where Director Jacob Forrsell explained the various processes entailed in the production of graphite, and particularly crucibles and electrodes. It was, indeed, a most interesting day.

The special train was again boarded the same evening and the journey continued during the night to Domnarvet, on the river Dal. Arriving here shortly after 7 a.m., the party was served with breakfast at the hotel, and afterwards visits were paid to the Domnarvet iron and steel works, the Kvarnsveden paper mill, a chemical works run in conjunction with the latter, and a new power station, all belonging to the firm of "Stora Kapparbergs Bergslag" —the largest private undertaking in Sweden. Capt. Frisel, Director Lof, and Chief Engineer Almgqvist, respectively, took the party in hand, and explained everything in the fullest and freest manner. At the Kvarnsveden paper mill an opportunity was provided of witnessing in operation a new steam accumulator system recently installed by the firm of "Aktiebolaget Vaporackumu-



A Remarkable Steam Accumulator.

lator," of Stockholm. This applicance has for its object the equalisation of the steam production of boiler installations, so that they may be operated with practically constant firing, independent of the variations of the steam demand of the plant connected with the pipe lines, as well as of the unavoidable variations of power and fuel supplied to the boiler. The accumulator in question, of which an illustration is here given, seeing that it may possibly be of interest to users of steam plant employed in connection with pottery production, is charged with steam during periods of low consumption and automatically discharged at periods of high steam demand. In this way it is claimed that the steam accumulator serves much the same function for the plant as does the flywheel for an ordinary steam engine. The fuel economies by the use of this system are said to amount to from 15-32 per cent., and it is claimed that the period taken to recover the initial cost of the installation is normally from one to two years. The accumulator installed at the Kvarnsveden paper mills was stated by the principals to have satisfied all the demands made upon it, and they were prepared unreservedly to recommend its definite acceptance.

After having conducted the party round the various works mentioned, the proprietors of the associated concerns entertained the Ceramic Society to lunch, the rendezvous being a hostel belonging to the company at Domnarvet. Here, during luncheon, a telegram was read by Mr. Odelberg from the head of the company at Stockholm, Consul-General Soderberg, to the following effect: "On your arrival at Domnarvet I beg to wish you and our English friends welcome to the Bergslagets establishments. I should have appreciated being present on this occasion, but I regret that was not possible. I hope you will find the visit interesting, and that you will enjoy your stay with us."

The Church at Gustafsberg.

Sir William Jones said that he was sure everyone appreciated to the full the message of welcome which had just been received

from Stockholm, and on behalf of the Society he would like to express to Capt. Frisell and his colleagues their sense of appreciation of the way in which they had conduced to their instruction and enjoyment by conducting them round their several establishments. The morning's tour had been extremely interesting and instructive, and though it had been somewhat tiring, they would all have been sorry to have missed such a wonderful opportunity of seeing the facilities possessed by the oldest, largest, and most important industrial concern in Sweden. He understood that the prosperity of the company was founded upon the discovery and working of a copper mine at Falun some 700 years ago, whilst the more recent activities of the company were concerned with the iron and steel works which had been visited that morning, founded half a century ago, the pulp works inspected, which were established thirty years ago, and the by-products factory in connection with the latter, which was commenced some fifteen years ago. When one reflected that these concerns represented but a tithe of the properties of the company, one could the more easily appreciate the influence that the undertaking must exert in the industrial life of Sweden, if not, indeed, of other countries also. The toast, "Success to the Firm," was drunk with enthusiasm, and Capt. Frisell responded, expressing thanks for the kind sentiments of Sir Wm. Jones. He said they had tried to show the visitors at Domnarvet how their different establishments worked by the aid of natural resources, and by the utilisation of the most modern technical and economical apparatus, along with the sympathetic co-operation of the workers, in order to evolve a finished product that should find favour in the markets of the world.

The special train was boarded the same afternoon at Domnarvet Station for Falun, a town which owes its existence to the old Falun copper mine of the company already mentioned, which dates back to the thirteenth century. The mine is said to have yielded about 600,000 tons of copper, its largest output having been during the seventeenth century. Although the mine is still yielding copper, the chief output at the present time is rock, from which is recovered vitriol, sulphuric acid, red ochre, and some small yield of the rare metals. A wonderful museum, descriptive of the company's productions from its earliest days, is preserved in Falun, and this, as well as the mine, was visited by the party before taking train from thence to Elfkarleo, in the beautiful Dalecarlia territory.

On arrival at the adjoining station of Stallmon, the special train was, by pre-arrangement, backed on to a privately-owned light railway running from that station to Alvkarleby, and was stabled for the night in a delightful pinewood within earshot of the roaring waterfall, which, to quote from an abler pen, "is yet little encumbered with disfiguring waterworks, and, framed in a setting of dark pine woods, makes in its lonesomeness a stronger impression than even Trollhattan." Some of the party, whilst waiting for

dinner, went on to the Charles XIII. bridge (which has spanned the river since 1816) to watch the salmon leaping in the turbulent stream, and later much enjoyed their salmon dinner at the Elfkareby tourist hotel. The night was spent for the third successive time in the "sleepers" of the special train, to which had now been added a sumptuously appointed dining car, in which breakfast and lunch were served the following day.

At 9 o'clock on Thursday morning, June 1, the journey was continued 16 kilometres further north to Skutskar, where pulp mills and saw mills belonging to the K.B. Co. are situated, and afterwards the company's arrangements for the shipping of timber were inspected with considerable interest. Train was taken the same afternoon for Upsala, where Prof. Thore Engstromer graciously conducted the party round the laboratories of the University, and an opportunity was also provided of visiting the wonderful Cathedral there. Tea was taken at an open-air restaurant in the town, and the same night the journey was continued to Stockholm, where accommodation had been reserved for the entire party at the Grand Hotel, overlooking the quay.

Friday, June 2, was expected to be the "star turn" of the tour, and had been spoken of all through as Mr. Odelberg's "Great Day." A great day it proved to be, and that it will live for a lifetime in the memory of all who shared in it is beyond question. From the balcony of the hotel, at an early hour, the streamer "Gustafsberg VII.," the most recently constructed and best-appointed passenger boat belonging to the firm with which Mr. Odelberg is connected, viz. : "A. B. Gustafsbergs Fabriks Intressenter," was seen to be making its way to the quay, gaily bedecked with streamers, and flying both the Swedish and the British colours. After a most enjoyable and exhilarating sail of some fourteen miles, Gustafsberg—an island on the Baltic shore—was reached, and the steamer dropped anchor at Gustafsberg Harbour, where a cordial reception was encountered from Mr. O. W. Odelberg, the senior member of the family—now close upon eighty years of age—and Mr. Victor Odelberg, who is in charge of the agricultural interests of the community, as well as the housing and welfare arrangements.

The history of the Gustafsberg pottery is well worth recapitulating. The undertaking was commenced in a modest way in the year 1825. The factory at that time would have been more properly termed a clay works than a pottery, for it manufactured only the coarsest and commonest types of earthenware. It was owned by a wealthy Stockholm merchant—a relative of the Odelberg family—who, however, devoted but slight attention to it, and consequently it made, for a while, but little progress. Some twenty-five years afterwards a reconstruction took place, and a period of rapid progress commenced. A Staffordshire manager was appointed, in the person of Mr. Geo. Barlove, formerly with the firm of Davenport &

Pottery Workers' Houses at Gustafsberg.

Co., of Burslem, and a relative of Mr. Burgess, then of the firm of Burgess & Leigh. Mr. Barlove, who was responsible for the management of the factory for some years, and remained with the firm for the remainder of his life, died in 1909, whilst in retirement, and as a pensioner of the company. His early association with the factory was, however, quite sufficient to import English influences and to bring about the reconstruction of the factory on thorough English lines.

The community of Gustafsberg may be said to have grown round the pottery, and its geographical isolation has tended to make the community self-contained and self-supporting. This led up to a sort of pottery township very much on the lines of Bournville or Port Sunlight. As for the pottery, it is a model of ingenuity, thanks to the engineering mind of Mr. Axel Odelberg, who is clearly a past-master as a pottery engineer, and, above all, an electrician. It is only natural, of course, that electricity has played an important part in the development of the Gustafsberg pottery and community, since electrical power in Sweden is so economically applied. The writer recalls vividly a lecture which Mr. Odelberg gave to the Ceramic Society some ten or twelve years ago, in which he outlined how the modern magician—electricity—had been the means of transforming the Gustafsberg pottery from a concern of mediocrity into a live industrial enterprise, to say nothing of the part which electricity had also played in the social life of the pottery community there.

The visitors lost no time on their arrival at Gustafsberg in exploring the mysteries of Mr. Odelberg's wonderful pottery, and

they were clearly delighted with all they saw making for the production of earthenware on a large scale. A glost oven was being drawn as the party reached the works, and thus an early opportunity was afforded of seeing the automatic conveyor which was installed by Mr. Odelberg a few years ago, and of which he is legitimately proud. (See TRANS. **19,** 42, 1920 and **20,** 50, 1921).

A glance was also taken at a 22-ft. glost oven which was in the finishing stages, and it was interesting to notice how a down-draught oven was acting perfectly by means of a variety of controls, without any sort of outlet at the top of the oven. A 24-ft. biscuit oven was also seen to be of the perfect down-draught type. The firing is conducted to cone 4 down, Buller's rings also being employed, The underglaze printing department proved particularly interesting, inasmuch as not only one-colour printing, but three-colour prints were being applied by means of a roller printing machine, and it was generally conceded that the results were quite as good as could be achieved by flat coppers and hand printing, which is, as yet, very largely the practice in the Staffordshire Potteries. It was observed that the printing colours are prepared with oil between rollers, heated with steam, the oil and the colour being in this way perfectly blended. The roller printing machines are of the Hassall (Staffordshire) type, but suitably altered so as to be worked by electricity. Printing at the Gustafsberg Pottery is quite an important branch, for it was seen that practically 70 per cent. of the earthenware produced there is decorated by means of underglaze prints.

Mr. Odelberg showed with obvious pleasure his arrangements for the jolleying of square dishes. For this purpose he has a new patent device, which is protected in all the pottery producing countries, even as far distant as America, by means of which a perfectly rigid jolley is permitted freedom of movement in the jigger head. The making of saggars, the production of stilts, and last, but not least, the working of a new continuous tube-mill in the sliphouse, in which more than ordinary interest was centred, were inspected. Mr. Odelberg was confident as to the economies which this new continuous system of grinding would yield. He considered that it was the system of the future, and that before very many years are over, it will largely replace the older form of cylinder grinding.

After visiting the earthenware factory, a short trip was paid to another section of the concern, where bone china and electrical specialities are being made. Some members of the party also visited the power-house, where the electrical current, which the factory receives from Elfkarleby waterfalls, nearly a hundred miles away, at 20,000 volts, is transformed down to 500 volts. This power not only drives the pottery, but is utilised on the farms of the community, as well as by the local waterworks and for domestic purposes in the workmen's cottages. Incidentally, even the ringing

of the church bell is also dependent upon this power-house.

The Gustafsberg Pottery employs, all told, about 900 hands, and the village houses about 2,300 persons, all of whom derive their living from the success of the pottery, even to the agriculturists of the village. The houses belonging to the company are let out to the workers at a small rental, and during more recent years the policy has been adopted of allotting one house to one family. Naturally, however, there are many types of houses, but there is no overcrowding, since the housing arrangements are reviewed periodically and altered to meet any changes of conditions. Each house has its own allotment, and fruit and vegetables are largely cultivated.

As already mentioned, the Gustafsberg Company has its own fleet of steamers plying between Gustafsberg and Stockholm, and also possesses a large ocean-going steamer, which was seen at the quay unloading a cargo of raw materials from England. It is capable of bringing out about 1,800 tons of coal or clay each voyage. Three large ice-breakers are maintained by the firm in order to keep the waterway open during the winter, and the writer learned with interest that in spite of the hard winters that are experienced in these parts, Gustafsberg has not been shut off from navigation for the last twenty years. This seems quite creditable when one reflects that the island of Gustafsberg is in the Archipelago of Stockholm, and, therefore, not more than fifteen miles from the open Baltic.

After spending the whole of the morning at the pottery, the visitors were taken by Mr. Axel Odelberg to his own home—a pretty villa overlooking the harbour—where they were entertained by him to lunch. A little speech-making was indulged in between the courses. Mr. Odelberg expressed his delight at being able to welcome so many of his English friends to his own household. Some of them, he was pleased to say, had been there before, but he had always wanted to welcome a representative body of the Ceramic Society to Gustafsberg, and it had occasioned him more than happiness that so many had undertaken the long journey in order to pay his country a visit. He knew that everyone had felt at ease from Gothenburg onwards, but he hoped they would feel even more at home when he reminded them that the whole of the preparations for them that day had been in the hands of an English lady—Mrs. Odelberg. The Swedish newspapers that morning were full of all sorts of comparisons between Sweden and England, but he was inclined to think that it was personality which counted in both countries. In everything that the potters of the two countries produced this revealed itself. In Staffordshire he thought personality had counted in a remarkable way, and the same thing might be said of Gustafsberg. What they had been able to see that day had been built up from a very small scale by his revered father, Mr. O. W. Odelberg, who had been the life and soul of Gustafsberg

for the past fifty-three years. There was another thing he would like to refer to, and that was the spirit of camaraderie in which the pottery manufacturers seemed to take such pride. He had always been impressed by this on his numerous visits to England. and it was a spirit that had been even more developed since the founding of the Ceramic Society. It was because of this that he had been pleased that morning to show his English friends in the reality what he had previously endeavoured to show them through the medium of his films. The pottery industry was one of the oldest of crafts ; it dated back long before civilisation, when people dwelt in caves ; and so long as civilisation stood, so long would the pottery industry continue. Moreover, it was a constantly changing industry, and one that was difficult and complicated. Every morning one woke to discover something new. His last word would be this : the potters of no country must work and live for themselves ; they must strive to leave their footprints behind them for the benefit of their fellows and followers. He raised his glass to a good collaboration between the potters of Sweden and England.

Sir Wm. Jones, in returning thanks, made a fitting reference to the esteem which every member of the Ceramic Society entertained for Mr. Odelberg and his family. Words were inadequate to express their deep obligation to their host, not only for his unbounded hospitality, but also for the great amouut of painstaking care, as well as the remarkable organising ability, which he had displayed in connection with such an ambitious and instructive tour. It was perfectly true, as Mr. Odelberg had hinted, that all present felt a special attachment to Gustafsberg because of the fact that Mr. Odelberg, through his marriage, had forged another bond of union between England and Sweden, thus bringing close together the two nations. He (Sir William) confessed that up to that day he had never entertained any special desire to be a potter, but he was beginning now to wonder whether he had not made a mistake in the choice of his vocation, for Mr. Odelberg had succeeded in persuading him that potting was a most fascinating pursuit. Those who were present would never forget their visit that day to Mr. Odelberg's factory and home, and they would always reserve for him a sense of deep gratitude for his remarkable kindness and hospitality.

Mr. A. Fielding proposed the health and success of Mr. Odelberg's son. He said they had all seen and marvelled at what Mr. Thorsten Odelberg's father, uncle, and grandfather had accomplished at Gustafsberg, and there was little doubt that the third generation gave promise of pushing ahead in such a way as might well cause the British potters to look round the corners. "Just imagine a little country place like this," Mr. Fielding added, "right away from the civilisation of potting, and yet capable of accomplishing what we have seen to-day! Should it not be an

example to us?" Concluding, Mr. Fielding said he envied Mr. Odelberg, sen., and he regretted very much that the patriarch of the family was unable to be present at the luncheon in order to hear their appreciation of his sons, and the expectations that they all entertained of his grandson.

Mr. Thorsten Odelberg modestly replied, thanking the company for the kindness they had shown his father and mother by their visit that day to their home. He knew from his heart that it was one of the happiest days of his father's life.

In the early afternoon motor cars were taken round the village in order to inspect the workmen's cottages, the agricultural arrangements, the school, church, and so on, and later a sail was much enjoyed in Mr. Odelberg's steamer amongst the islands and bays beyond Gustafsberg. Afternoon tea was served on the steamer, and the return journey was made to Stockholm the same evening.

On Saturday morning, June 3, a number of visits were paid in and around Stockholm to industrial concerns, including the L. M. Ericsson Telephone Works, the Stockholm technical schools and laboratories, and the well-known Rorstrand Pottery, where the party was welcomed by the brothers Almstrom and shown round the entire factory, which was founded some 200 years ago. It is, therefore, one of the oldest factories manufacturing ceramic products in Europe, and one that has probably had the longest unbroken record. It was interesting to note that the factory occupies the site of a sixteenth-century castle. Towards the end of the eighteenth century the concern was entirely identified with the manufacture of enamelled earthenware. In 1782, however, a factory was also bought at Marieberg, the products of the two factories being, even at that early date, of good quality and well decorated. At the end of the eighteenth century the manufacture of enamelled earthenware was abandoned and the manufacture was commenced of a product which was imitative of the fine Queen's ware of Wedgwood. Whereas, in 1850, the personnel of the factory was 200 workers, by the end of the century the number of workers had been increased to about 1,000. Up to 1850, only fine faience was manufactured, but with the opening of the twentieth century the factory was making a tremendous variety of goods, including majolica, sanitary ware, English soft porcelain and Continental hard porcelain, for utility and ornament. Meanwhile the company exploited its own mines for felspar and quartz.

The modern products of Rorstrand are extremely varied. In walking round the works with Mr. Almstrom the writer was informed that the firm makes nowadays no fewer than 25 different bodies. Our informant doubted very much whether there was any factory the world over that could be said to be making so miscellaneous a range of pottery, from sanitary ware up to fine china. The Rorstrand factory also transacts a huge business in electrical porcelain, which is manufactured in all sorts of weird contrivances,

from the smallest speciality up to huge pieces—some 5 or 6 ft. in height. In this connection the testing of high-tension insulators up to a strain of 70,000 volts was witnessed, and proved particularly interesting to those members of the party who are engaged in the production of electrical porcelain in England. The majority of the small electrical specialities are die-pressed from clay dust; the larger and more important pieces, however, are thrown, jolleyed and turned.

In the preparation of both their earthenware and their bone china the Rorstrand Pottery use quartz instead of flint, which they obtain from their mines and prepare by calcination. The felspar they use is Swedish, and the ball and china clay they obtain from England. A water-way adjoins the back of the works, and here a lighter was seen discharging imported raw products. The kilns are fired with Newcastle coals, and we were interested to learn from Mr. Almstrom that during the war they paid at one time as much as 285 Swedish kroner per ton, equal to approximately 30 English pounds at the present rate of exchange. They bought 3,000 tons of coal in one contract at that price to enable them to carry on. Now, however, the price is down to about 30s. per ton landed at Stockholm—a statement that is likely to be read with interest by Staffordshire manufacturers.

An inspection of the sliphouse revealed that the whole of the power at the factory is now electrical, and, as in the case of the factories previously referred to, the current is received at the works at a high voltage—in this case 7,000—and is transformed down in the firm's own transformer house to about 500. The electrification of the factory is quite a recent move, having been completed only about a year ago. The clays are lifted to the top floor of the building and are there blunged up, gravitating down to the bottom floor where the filter presses are situated. The sliphouse is not particularly modern; in fact, it was built some forty years ago; at the same time, it is arranged on thoroughly practical lines. It was noticed that the firm goes in for the extensive storage of finished clays in the cellars, which run beneath the whole of the factory buildings. In reply to a question as to how long they prefer to store their finished clays before using them, Mr. Almstrom, with ready wit combined with perfect truthfulness, replied: "As long as possible."

There was no doubt, in traversing the various workshops and warehouses of the Rorstrand Pottery, that the Swedish potters have continually looked to Staffordshire for their impulse, both in a technical and artistic sense, for there was much to be seen that was definitely remindful of what is being done by the English potters. In many cases, where differences in the common practice were noticeable, one could imagine that these had been brought about by the absence of facilities in Sweden that are so common in Staffordshire as to be regarded as unimportant. It was observed, for

instance, that the saggars at the Rorstrand Pottery are made from china clay and grog. It is doubtful, however, whether this expensive method of making saggars would have been adopted had there been, within easy reach of Stockholm, such saggar marls as Nature has bountifully scattered around the Potteries.

There was much of interest to be seen at the Rorstrand Pottery which we have not the time or the space to record. Certainly everyone came away from the factory feeling that the concern is a live one, and that the proprietors have much to be proud of—particularly in regard to the way in which they have kept up-to-date in the development of specialities in electrical porcelain. Here again, however, it is conceivable that the trend of the country has forced the pace, particularly when it is remembered that the pottery factories of Sweden are not numerous, and that the results of progress are therefore consolidated and capable of being seen in their entirety within a narrow circle. It was interesting to hear in this connection that the electrical trade in Sweden is at present passing through just as bad a time as in England. One of the shops at the Rorstrand Pottery making electrical fittings had only four women working where forty were working a short time ago. As in England, however, the potters over there are expecting a turn in the tide before long.

On Saturday evening, June 3, the members were entertained by Mr. Odelberg's firm—Gustafsberg Fabriks Intressenter—to a banquet at Hasselbacken—a famous garden restaurant. It was a brilliant and memorable gathering, being graced by the presence of His Excellency K. H. Branting (the Prime Minister of Sweden), who was supported by a distinguished company, consisting of Cabinet Ministers, members of the Swedish Parliament, Government officials, Sir Colville Barclay (the British Minister in Stockholm), members of the English Legation, and numerous financial and industrial magnates.

A formal welcome having been extended to the guests by Mr. A. S. W. Odelberg, dinner was served to the strains of English music, and everyone was speedily at home. The speeches were few and well chosen to the occasion. The loyal toast having been honoured, Sir Wm. Jones rose to respond to a further toast, "The Ceramic Society." He first took the opportunity of returning thanks for the unbounded hospitality which had been met with on all hands during the week that was just coming to a close, and particularly at the hands of Mr. Odelberg's family during the past two days. He said he could not help feeling that the interests of the English and the Swedes squared from many points of view; the customs, methods and ideals of the two countries were very similar. He and his colleagues had had the opportunity during the past week of forming a better impression of Sweden and her enterprises, and they were all prepared to concede that everything they had seen had been absorbingly interesting. Most wonderful of all

was the application of water-power in Sweden to industrial needs. This was one of the marvels of the tour. Visits such as these between the representatives of particular industries should, he thought, make for the promotion of the most friendly relations, for one effect of them would be to establish a closer contact, and make for friendships of a more intimate kind, thus establishing deeper confidence. The Ceramic Society's trip to Sweden, after having been unavoidably deferred, had now become not only an accomplished fact, but an unqualified success, and they were all deeply conscious of the hospitality which had been shown them. Proceeding, Sir William said that it was rather difficult on such an occasion as that for an Englishman to speak without referring in some way to the late war. The circumstances and the trials connected with the war had become so instilled into their minds and lives that it was almost impossible to refrain from making comparisons of pre-war and post-war conditions. One could not help reflecting upon the political, industrial and social changes which had taken place. "You Swedes," concluded Sir William, "can probably see more clearly than we can the effects of the changes, since you have had the advantage of watching the prolonged and titanic struggle from a distance. You have seen political governments overthrown, credits destroyed, exchanges unstabilised—the whole world made to suffer, as it is doing at present, through depression and lack of confidence. We in England have been beset by many difficulties. We have had strikes in most of our staple industries ; but I think that could only be expected ; indeed, the wonder to me is that the troubles following the war have not been greater than they really have. One could not expect to have a European upheaval and then have things settle down in a day, a year, or even several years. I believe, however, that we in Great Britain have passed through our worst troubles, and I trust you in Sweden have also. What we have all to work for now, no matter what our nationality may be, is an enduring peace—a restoration of confidence between the nations. This can best be done by what Mr. Odelberg described yesterday as "a good collaboration." It is because of this that I believe that visits such as my Society is now paying to your country are of inestimable value, not only to us, but to you. I believe that such visits should be of untold good to us both. We wish you and your country peace, happiness and prosperity. May Sweden and Britain long continue to be friends, and may our friendship grow closer and still closer. I raise my glass and call upon my colleagues to drink to "Sweden and Swedish prosperity."

The toast in question brought the Prime Minister, Mr. K. H. Branting, to his feet. His Excellency said that he was indeed glad to be able to see present so many eminent representatives of the English ceramic industry—an industry which, for a long time past, had occupied such a prominent position in the markets of the world.

The ceramic manufacturers of Sweden were naturally very glad also to welcome such distinguished visitors, and for the opportunity which the visit had afforded them of showing their factories and the class of work that is now being carried on in Sweden in this the oldest branch of human activity. He earnestly hoped that the industry would long continue to flourish in both countries, and that it would succeed in producing objects that were not only of great artistic value, which was always one of the chief aims of the industry, but also at such prices as would bring them within the capacity of the great mass of the people, and so help to raise the agreeableness and beauty of their daily surroundings. He was pleased to extend a welcome to the guests, not only as ceramic producers, but as representatives of the great British Empire. He hoped sincerely that their coming to Sweden would contribute to, and still further strengthen, the excellent relations existing between the two kindred countries. He hoped that the visit might also bear fruit in establishing still more intimate relationships between the peoples of the two countries in the realm of commerce, promoting that mutual understanding which was at the basis of all prosperity and success. Sir William Jones had expressed these same sentiments in a manner with which he could entirely associate himself. Actuated by these sentiments, he raised his glass and proposed the very good health of their English visitors, who had done them the honour of coming over to see and study Sweden and her people. Concluding, the Prime Minister said: "Let me not forget at the same time that to-day is the birthday of King George of England. Gentlemen, I give you 'The good health of your King.'"

This rousing speech of the Prime Minister naturally resulted in the singing of the British and Swedish national anthems, and a happy entente supervened. Mr. Odelberg later had an opportunity of making his best speech of the trip. He said that the Swedish potters felt honoured that they should be the first of the "small countries" to be favoured by a visit from the Ceramic Society. But the fact that Sweden was spoken of as one of the "small nations" was no reason why the trip should be any the less interesting; indeed, this factor might be even an advantage, for just as it was easier to organise and control a small business than a large and extensive one, so it was easier to survey a small country than a huge one—it offered a less complicated field of study. Social, industrial and commercial reforms were perhaps the more quickly carried through in a country like Sweden, for there was bound to be more flexibility. He sincerely hoped that his guests would not have cause to repent the time spent in visiting Sweden, and that they would get something in return for their visit. He thanked his own countrymen also for lending their support. He said he was specially indebted to His Excellency Mr. Branting, and to Sir Colville Barclay and the other members of the English Legation, as well as to the many leading men of his country who had sacrificed

their time to show their interest in the visit. "To the English Ceramic Society; to a successful trip; to a good collaboration between Sweden and England, for the benefit of all parties, master as well as man, I raise my glass," said Mr. Odelberg.

The function was a very fitting finale to the official programme in Stockholm, and during the following two days, which were both national holidays in Sweden, the visitors followed their own pursuits, and prepared themselves for a strenuous time immediately the Whitsuntide holidays were concluded.

On Monday evening, June 5, the special train was again boarded at Stockholm, and the last stage of the tour in Sweden commenced. On the way from Sweden into Denmark a halt was made at Höganas, which place was reached about 8 a.m. on June 6, and here the party was met and welcomed by Mr. K. J. Beskow, director of the Höganas-Billesholms Co. Breakfast was partaken of at a hotel in Höganas, and immediately afterwards a tour was made of the town, particularly with a view to inspecting the housing and welfare arrangements that are made by the Höganas-Billesholms Co. for their workers. A visit was afterwards paid to one of the lecture halls of the town where a complete collection of the productions of the company had been specially got together for the benefit of the visitors, in order to give them a better impression of the many-sidedness of the company's undertakings. The company had also been thoughtful enough to request one of its directors to give an explanatory sketch to the visitors of the origin, development and present scope of their operations, so as to prepare them for what they would later be shown when visiting the works. Höganas, it was explained, is one of a series of eight or nine communities which have grown up around the company's industrial undertakings, and the place owes its existence to the fact that in this neighbourhood the very modest coal deposits of Sweden are all situated. Unfortunately, a considerable part of the coals obtained is of a low quality, containing a high percentage of ash. This circumstance, in conjunction with the fact that clays of very different qualities, such as good fireclays and excellent pipeclays, occur conjointly with the coals, is the fundamental basis of the clay-working industries which are carried on by the only coalmining enterprise in Sweden.

The clay-working industry of Höganas is now of considerable age. As far back as the year 1825 a factory was erected for the manufacture of refractory bricks, and shortly after this the first pottery was started. At the commencement, apparently, not very much was attempted, but by the end of the nineteenth century a continuous firing system was introduced in connection with the gasification of the inferior coals, and to this continuous kiln the modern plants of the Höganas-Billesholms company may chiefly be attributed. The company's own clays are, in the main, employed. The coal measures contain regular strata of

clays, in close connection with the coal beds, and because of this, the mining of coal and clay is carried on contemporaneously. The clays are principally bituminous, containing, as a rule, anything from 1 to 2 per cent. of bitumen up to 20 or 30 per cent. Further, the clays distinguish themselves by a high percentage of alumina, and, as a consequence, they are generally refractory. By burning the coal in the bituminous clays, chamotte is obtained, and this chamotte is added as grog to raw clay in the production of refractories.

Many different qualities of firebricks are manufactured at the company's plants. The works at Höganas principally produce common firebricks with a low percentage of alumina, while the works at the neighbouring village of Bjuv make bricks containing up to 43 per cent. of alumina. In certain cases the alumina is increased still more by the addition of calcined bauxite or electrically fused alumina. At Höganas silica bricks are also made. The raw material for these bricks is derived from Dalsland, a province in Central Sweden, where the Höganas-Billesholms Co. are the proprietors of large deposits of quartzite. Building bricks are also produced at Höganas. The raw material for these bricks consists of up to 60 per cent. of ashes from the gas producers. This ash still possesses some content of coal, which is almost sufficient to bring about the burning of the bricks. Recently, the manufacture of another type of refractory brick has been commenced at Höganas, viz. : a silicon carbide brick, which is claimed to have many advantages over the ordinary fireclay brick.

At Hoganas a certain amount of salt-glazed pottery, fireclay sanitary ware, and ornamental pottery is also produced. A little time ago the manufacture of white sanitary ware, such as wash-stands, bidets, pans and traps, etc., was commenced. In this latter case, however, a certain amount of imported clay in addition to that of the firm is employed. Besides the productions of the works at Höganas, fireclay materials, building bricks and roofing tiles are produced by the company at Skromberga, Hyllinge and Bjuv, whilst there are similar plants for the production of bricks and pipes at Stabbarp, Axeltorp and Vallakra.

A point worth mentioning is that the company has made extensive use of electric power in its various factories. The current is generated by two power stations, one at Höganas and one about 25 kilometres distant, the capacity of the two stations being about 12,000 h.p. The power is obtained from the burning of the most inferior coals in tube boilers with automatic firing. Electrical power is sold to a power company in the south of Sweden, with whom a mutual arrangement has been made that power shall be delivered to the Höganas company from certain waterfalls in the province of Halland when the supply of water-power is good, whilst the Höganas Co., during other times, shall deliver electric power produced by means of coal to the water-power company. The

result of this arrangement has been that it usually happens that the water-power company delivers power to the Höganas company nightly, whilst the Höganas company delivers power in exchange during the daytime.

The number of employees at Höganas is now about 4,500, of whom about a third live in houses belonging to the company—the remainder in their own houses. Those workmen's dwellings which belong to the company are generally built for two families, but in certain instances for four families, whilst the houses which belong to the workmen are mostly arranged for one family only. Special arrangements are made for the comfort and pleasure of the people, such as public baths, public kitchens, lecture halls, parks and recreation grounds. Altogether the company's plant covers an area of about 158 acres, whilst the floor area alone of the combined works amounts to about 39 acres. If the whole of the kilns which the company possesses were to be applied to the burning of ordinary building bricks, the company estimates that it would have an output of about 160 million bricks annually. The principal market of the company is Sweden, but a certain amount of export trade is negotiated with the European countries generally, and also as far distant as South America and Java. The export trade is chiefly concerned with bricks having a low percentage of alumina.

A visit was afterwards paid to a pipe works of the company, where some very up-to-date machinery was seen in operation. One of the chief items of interest was a hydraulic press now in course of erection for the making of carbon electrodes. The total weight of this press was no less than 170 tons. The success of the company seems particularly due to the wonderful use they have made of materials which, in England, would be regarded as useless and only fit for the scrap heap. "I am positively angry," said one of the principals of the company to the writer in the course of conversation, "when I go to England to see what the mine-owners there are throwing away. If they were only to display a moderate amount of economy they would be able, in my opinion, to generate from the materials which are now being wasted sufficient power for the whole of England's industrial needs. The whole of our industry is based upon coal which contains 50 to 60 per cent. of ash. The firing at our stations is performed automatically, and one man is capable of handling over 400 tons of coal per day. The coals are crushed, fed into hoppers, passed down into the cellars as ash, and from that material we can generate as much steam as you in England are getting with your best coals."

After having visited the Höganas-Billesholms Co.'s pipe works the party was motored by Mr. Beskow to Molle—a beautiful seaside resort on the shore of the Kattegat—where they were entertained to an excellent lunch at the Hotel Elfverson, which is situated on high ground in full view of the sea, and within sight of Denmark. The

occasion provided Mr. Beskow with an apportunity for making a capital speech, which was to the following effect:—

"To the President, Secretary and members of the English Ceramic Sociery, as well as to the ladies who have accompanied them, may I express, on behalf of the Höganas-Billesholms Co., our joy that, while travelling in Sweden for the purposes of study, you have been willing to spend a few hours at the oldest and largest works of our company. It is not for me to speak of the profit you may have derived from this visit. In one respect, however, I presume it has been agreeable, for it has brought you nearer your homes, for which you are naturally longing after such a long sojourn abroad. You may have come nearer your home country also in the respect that what you have seen here may remind you more of England than, for instance, the roaring waterfalls of Trollhattan, the sombre pine-woods of Dalecarlia, or the skerries and rocks of the Stockholm archipelago. Indeed, we like to fancy here that Höganas has a rather English stamp. This should not cause surprise when it is remembered that at least the first forty years of the history of the Höganas works was affected by English management and English influence.

"The Scanian earth contains, besides considerable quantities of coal, such clays as are suitable for ceramic purposes. Not taking into consideration the traces of primitive pottery-making carried on by our forefathers on this coast, we still preserve specimens from the last few centuries of more typical ceramic pro-

The State Power House at Trollhattan.

ductions, such as tile hearths and fireplaces, Delft ware and artistic earthenware, manufactured at several places in this neighbourhood.

"The Höganas works derive their origin from one of these ceramic enterprises—the manufacture of salt-glazed pottery in Halsingborg. The finding of a clay in Höganas, which in 1796 was offered to this factory, led to borings in Höganas, resulting in the discovery of the coal-beds there. These finds caused the formation of a mining company, whose first important step was to call in Mr. Thomas Stafford from Newcastle-on-Tyne, in order to begin coalmining on a larger scale by the application of English methods. Mr. Stafford was active here as technical leader from 1796 until his death in 1831, and his perseverance and energy were such that his name can never be forgotten in the history of Scanian coal and the associated ceramic industry. The enterprise had to struggle with many difficulties so usual when a new business is started. In our archives we have a report from Stafford to the company's managing director, which exhaustively describes a number of his technical difficulties and troubles. It winds up by saying that if, in future, somebody finds this report, he is likely to believe that he has found 'a second edition of the lamentations of Jeremiah.' The enterprise did not begin to pay until, towards the end of Stafford's life, the coalmining was combined with the making of firebricks. Consequently, our industry owes its existence to the combination of the ceramic industry with coalmining. In quality our coals cannot cope with the English coals, and it was only during one period—the war, from 1914-1919—that the coalmining, from an economical point of view, was more important than our ceramic industry.

"If our industry was founded and, during the earlier part of the nineteenth century, developed, utilising the experience of English industry, we have, during the latter part of the nineteenth century, with regard to the coalmining as well as our ceramic industry, received strong impulses from our neighbour to the south—Germany. At the same time, we think that we here have also to a certain degree developed the ceramic industry, for we have not altogether copied others. Especially under the direction of our Mr. Sieurin new technical methods have been introduced which have won the approval of foreign experts. In connection with this, I will mention that the problem of producing iron sponge on a larger scale has been solved by Mr. Sieurin by applying some of the resources of the ceramic industry. This method has been employed also outside the boundaries of Sweden. I will also mention that workers, migrated from Höganas, have greatly contributed to the founding and development of the Northern Co., in the U.S.A. I have been told that, among other things, furnace constructions are being used there which very much remind one of those used in Höganas.

"With these words I have touched upon a small part of the

wandering of ceramic technics over the globe. I know that the Ceramic Society was founded principally with a view to raising the ceramic industry of England by the aid of science, and that it rendered good help at a moment when the country was in the greatest need of mobilising all its resources. But science in general, and technical science in particular, must be more or less international. The results which the Ceramic Society achieve will thus finally be to the benefit of all mankind. If, then, I give expression to the hope that these results in future may serve the peaceable development of the world, I am convinced that you will all heartily join me. With these words I am happy to propose 'Our English Guests.' "

Sir William Jones responded, remarking that the Society's journey through Sweden appeared to have been one long triumphal procession. They seemed to be passing from one hospitality to another. Indeed, he was beginning to entertain some trepidation in his mind as to the ultimate results on the members when they returned home. He was pleased to recall, and his colleagues also would no doubt rejoice in the fact that, in 1914, whilst in office at the Ministry of Munitions, he visited the Hoganas-Billesholms Co. and entered into a certain amount of business with them. That this business should have been made possible through the early work of an Englishman from Newcastle-on-Tyne was all the more interesting. All that they had seen that morning stood to the credit of the company, and he and his colleagues were delighted to have been permitted to view such an important and wonderful organisation.

Mr. H. J. C. Johnston, the President of the Institute of Clay-workers, supported Sir Wm. Jones in his expression of thanks. He said that they had seen many interesting things that morning, and they appreciated to the full the efforts which had been made by the members and staff of the company to furnish them with all the information that they wanted. To Mr. Sieurin, the engineer-in-charge at the factory, and also to Dr. Svenberg, the head of the mining department, they were particularly indebted. The experiences that had been met with in Sweden, which were now rapidly drawing to a close, would, he was sure, increase the regard of all the members of the delegation from the English Ceramic Society for the Swedish industrialists; indeed, for the Swedish race in general.

Mr. Odelberg also added his quota of thanks to the directors of the Höganas-Billesholms Co., and immediately following the luncheon, the party was motored back to Höganas Station, where three cheers for the hosts were called as the train moved out of the station. Three-quarters of an hour later the party was aboard the ferry at Halsingborg; the Sound was crossed to Elsinore, where the passports were examined, and Denmark entered. The afternoon was spent in visiting the Castle, and in the evening dinner was

served at "Marienlyst," a neighbouring seaside hotel. Train was taken late the same evening for Copenhagen, where the members were accommodated for the remainder of the trip at the Palads Hotel.

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Although one now realises that not more than about a quarter of the time involved in the complete tour was spent in Denmark, one has to admit that those three concluding days of the trip constituted something like a record of activity. In Sweden the sight-seeing had been remarkably varied and rather widely diffused—it had actually entailed well over 1,000 miles of travel from Gothenburg to Halsingborg, taking into account the numerous detours and motor journeys. In Denmark, however, everything in the way of works inspections was practically confined to the clay-working industries and was centred in and around Copenhagen, the result being one concentrated bout of functions and sight-seeing. From morning until late at night the members kept on the move, and there was packed into those three days as much information as one could have been expected to absorb anything like completely in a whole month.

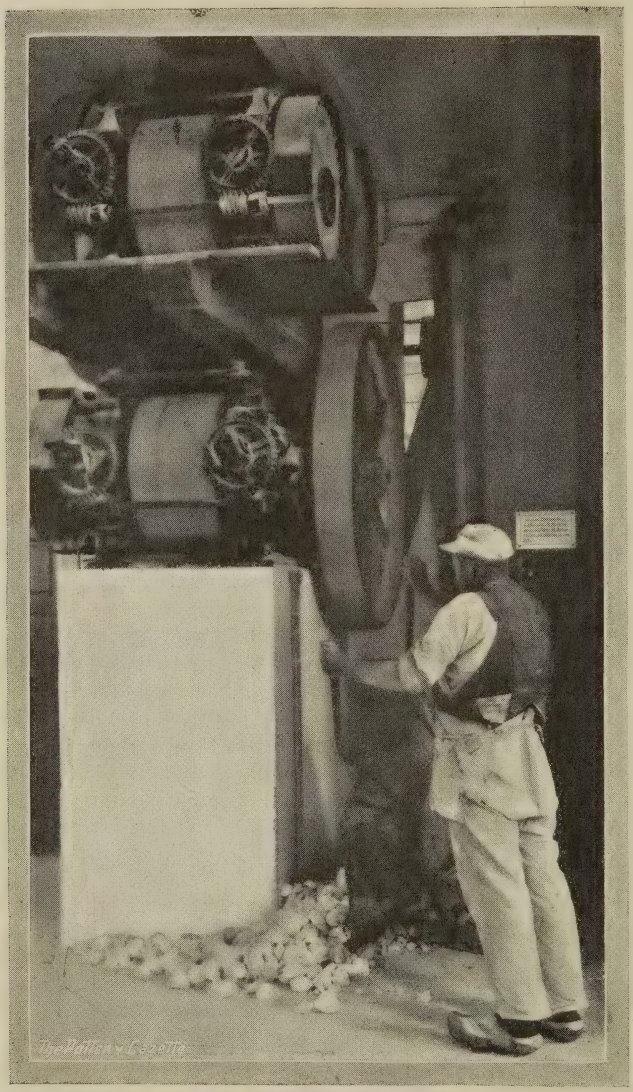
The general arrangements for this latter part of the tour were now undertaken by two representatives of the firm of F. L. Smidth & Co., of London and Copenhagen, in the persons of Mr. C. A. Møller and Mr. H. C. Michelsen, for Mr. Odelberg had announced his intention the previous night of relinquishing his responsibilities as guide immediately the shores of his own country were left behind. It can be said here that the arrangements which had been made by these two gentlemen on behalf of their firm were most thorough, and that the programme was carried through without a hitch, with the single exception of a dinner which was to have been given by F. L. Smidth & Co. on the last evening in Denmark, which was spontaneously cancelled by the Ceramic Society when the news was received, after arrival in Copenhagen, of the death of the wife of one of that firm's directors. Messrs. Møller and Michelsen, who accompanied the party through both countries, proved admirable companions as well as guides, and their firm is to be congratulated upon the arrangements which were made on their behalf.

The first serious item in Copenhagen, on Wednesday morning, June 7, was a visit to the Polytechnical High School of Denmark at Solvtorvet, where a formal reception was extended by the chief director, Prof. P. O. Pedersen, who greeted the visitors with the following words: "Ladies and Gentlemen, to-day you will everywhere, in our little country, be received as our highly esteemed friends, and everywhere you will receive our heartiest welcome. I hope that when you leave our country in a few days' time, you will have found that nowadays there is something right and something good, though there may have been, at some time or other, 'something rotten in the state of Denmark.' "

In the lecture hall later two papers were read, which were really introductory to the works visits which were to be made subsequently. These two papers, the first entitled: "The Ceramic Industry of Denmark," by Mr. C. Jacobsen, and the second: "Modern Grinding Methods in the Ceramic Industry," by Mr. C. J. Møller, will be found in the TRANSACTIONS, on pages 20 and 12 respectively.

Sir William Jones, in returning thanks to Prof. Pedersen for presiding, and to Prof. Jacobsen and Mr. Møller for their interesting addresses, said there seemed to be no doubt about it that the ceramic industry, probably more than any other of the important industries of the world, combined art with science. The artistic side of the industry was always more or less a matter of individual genius, as Prof. Jacobsen had pointed out when referring to the temporary decline of the fortunes of the Royal Copenhagen Factory, through the loss of its former artistic greatness—a loss that had since, happily, been made good by the rise of further individual geniuses. But the scientific side of the industry owed everything to the patient, systematic and combined research work of many who consistently worked with a view to its advancement. That research work had only been appraised at its full value within comparatively recent times. In England the Ceramic Society owed a great debt of gratitude to Dr. Mellor, and, so far as Denmark was concerned, everyone hoped that the work which had now enthralled Prof. Jacobsen might be productive of the highest possible results. Prof. Jacobsen's paper had been quite a historical narrative of the growth and development of the ceramic industry of Denmark. Mr. Møller's paper, which had given full details of the Smidth system of grinding, seemed to be of a rather more controversial nature, and there was little doubt that, if time had permitted, there were to be found amongst the visitors several gentlemen who would have been glad of the opportunity of discussing the details of some of the processes which Mr. Møller had described. Time, however, did not permit, and consequently, any discussion upon Mr. Møller's paper would have to be deferred until their return home. They were all extremely delighted to have been provided with such an interesting morning, and their thanks to all concerned were very sincere.

Dr. H. G. Colman supported what Sir Wm. Jones had said. He remarked that, apart altogether from the value of the two addresses which had been given—and they undoubtedly were very valuable—he and his colleagues all entertained a feeling of admiration and envy, which was not unmixed with a certain amount of personal shame, when they reflected that Prof. Jacobsen and Mr. Møller—both Danes—had addressed them very successfully on highly technical subjects in the English language. Everywhere throughout the trip they had been impressed with the same thing. One could not help feeling that it was high time that Britishers took up the



Roller Crusher at Copenhagen.

study of languages other than their own.

Following these lectures the party was motored over to Prof. Jacobsen's laboratories, where much interest was displayed in his various forms of testing apparatus, as also in a special collection of pottery productions drawn from all parts of Denmark in illustration of what he had already said in his lecture that morning. From here motors were again taken, this time for the Norden Porcelain Factory, in the adjoining grounds of which Mr. Bing entertained the party to what was described in the programme as a "light luncheon." A wit of the party was overheard to remark that it was fortunate that Mr. Bing had not decided upon a "heavy" luncheon, for once again the hospitality was quite lavish.

After the luncheon the Norden factory was explored, and proved to be wonderfully well equipped for the manufacture of electrical porcelain on a mass-production scale. Erected quite recently, the factory in question has been designed on thoroughly economic lines, and fitted with the very latest and most up-to-date appliances. Consequently, the firm is laid out for a heavy output. It was noticed, however, that in common with practically all the other works that were visited—particularly the electrical porcelain works—there were but few orders on hand for the time being, the depression in trade being quite as acutely felt here as it is being felt at home. Nothing in the way of manufacturing processes was held back during the tour of the works, and questions were even invited. As a consequence, a most enjoyable hour and a half was spent.

The artistic porcelain works of Bing & Grøndahl were afterwards visited, but here the party for the most part chose to remain content with an inspection of the company's museum and showroom, although a few of the more enterprising spirits elected also to visit the firm's laboratories. It was now getting rather late in the afternoon, and seeing that it had been arranged that the visitors should be the guests that evening of the principals of the four leading Copenhagen factories, there was naturally a generally expressed desire to take a little respite in the meantime.

At the Restaurant Nimb, in the Tivoli Gardens, the same evening, a banquet in honour of the visit of the English Ceramic Society was given, the hosts being Bing & Grøndahl, the Norden Porcelain Factory, the Copenhagen Faience Factory, and the Royal Copenhagen Porcelain Works. It was a brilliant function, and one that led up to expressions of the warmest sentiments. Mr. Frederik Dalgas, the chief director of the Royal Copenhagen Porcelain Works, in toasting the Ceramic Society of Great Britain, began by expressing the view that, for her national entity, Denmark owed much to Great Britain, and in this regard Denmark would never forget her obligations. Coming more to the present occasion, Mr. Dalgas remarked that their guests had that day had the privilege of seeing the Norden Porcelain Works—the newest pottery factory

in Denmark. To-morrow he would hope to have the pleasure of showing them the oldest of the Danish potteries, now 150 years of age. One fact would no doubt impress the visitors during their round of the various Copenhagen works. There was something about Danish pottery that was not quite so noticeable in the pottery productions of other countries; there was something really national about it. Danish pottery was, in fact, based upon national culture; it was closely connected with the thoughts and feelings of the people. The potters of Denmark, for a long time past, had felt that they must show the world, through the medium of their productions, that Denmark exists, and that she has a right to exist. This spirit was not only revealed in the pottery productions of Denmark; it was evinced also in certain other industries, but he naturally chose to speak of the one in which he was most vitally interested, and, incidentally, the one that he so much loved. He hoped that this feeling of nationality and national culture would long continue to be revealed in the productions of his country, that it would last as long as the spirit of "Rule, Britannia" in Britain—and that was likely to be a long time. He realised, of course, that the British potters had made for themselves a tradition which the Danish potters might have some cause to envy—a tradition that no other country in the world, with the single exception, perhaps, of China, could lay claim to. To speak of ceramics was to speak of England. There was no doubt about that. For this reason, therefore, the Danish potters were proud to welcome their English confrères, and they would be proud to be able to say in the days to come: "They came here as our guests." They were delighted to feel that the representatives of the English potters had come to Denmark as their friends; they would like to retain that friendship always. "We in Denmark consider this occasion to be a privilege and a joy," concluded Mr. Dalgas. "To our healths, then, and to our friends and guests."

Once more it was to Sir Wm. Jones that the Ceramic Society looked to voice its expressions of thanks, and the spokesman rose to the occasion admirably. He led off by repudiating the idea that Denmark was ever under any obligation to England; on the contrary, Britishers were under an everlasting obligation to Denmark for the gift of Queen Alexandra—the Queen and Consort of our late beloved King Edward, who did so much for the world and for humanity. The Ceramic Society, during this particular tour, had been simply overwhelmed by hospitality, and it was becoming increasingly difficult as the tour progressed to voice the thanks of the Society adequately. They had visited that moring Denmark's Polytechnical High School, where they had listened to two most interesting papers; and they had visited during the afternoon two up-to-date porcelain works, which had filled them with admiration, not only from the aspect of the scientific way in which, in the first instance, intricate precision work in technical porcelain was

being produced, but also from the point of view of the welfare considerations that were entertained for the workpeople. Speaking for himself, he did not think he had ever been through brighter or more attractive workshops than those they had seen that day. In the second instance, they had had the opportunity of visiting a factory where art was the handmaiden of science. He was afraid he was not qualified to say much in regard to the artistic side of pottery production, because he was not a potter, but he would ask two of his friends from the Staffordshire Potteries to follow him with a word or two on that subject. He would, however, like to say that the open-hearted manner in which the Copenhagen potters had laid bare their works and methods had struck him as indicating a broad-mindedness which was calculated to make one think of the Danish potters as being big men, who feared no competition, but who felt that experience and personal ability counted for more than all else. He had consistently preached in his own country the desirability of trying to conduct business on broad-gauge lines, and he was always out to claim that co-operation on such lines would make for the good of all engaged in any particular industry; indeed, he regarded this to be the first essential to the success of any industry. The Danish potters had that day set an example which the British potters might worthily follow. He felt that international meetings such as this, between members of the same or related industries, could only have one effect—the good of all who shared in them. He was quite sure that, if ever the Danish potters thought fit to pay a visit to England, his friends of the Ceramic Society would endeavour to emulate the high example that they had been set that day, and give their friends a reception as worthy and as hearty as they themselves had been accorded in Copenhagen. He would conclude by expressing the devout hope that the happy relations between Great Britain and Denmark might proceed, as time went on, from strength to strength, and never be disturbed.

Mr. H. E. Wood, the President-elect of the Ceramic Society, who said he was proud also to be counted as one of the original members of the Society, and, he believed, the only one of the original members sharing in that particular tour, said that he naturally felt happy to think that he had taken part in any of the early efforts of the Society, seeing that one result of these early efforts had been to sow the seeds for international gatherings such as this. He was proud also to think that the Ceramic Society had been the means of very largely dispelling that desire for secrecy that was at one time entertained within the circle of the pottery trades. He believed, with Sir William Jones, that much more was to be learned all round by displaying a spirit of open-mindedness. He had been interested to see, in going round two of the Copenhagen factories that day, that the Danish and English potters were brethren in one respect at all events—they each had their troubles. He had seen sufficient to satisfy him that not all the articles that came from

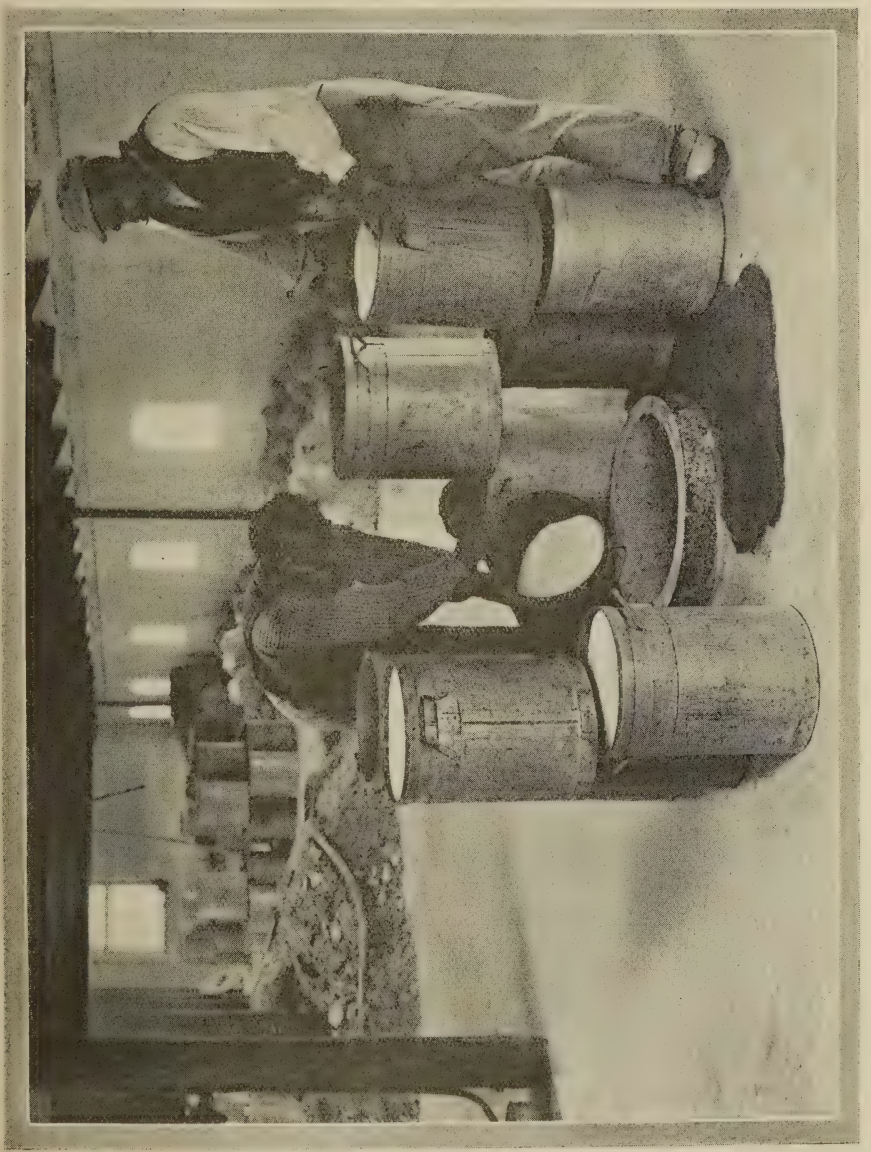
the hand of the potter found their way into the museum or the showroom, or even the packing-house. That being so, each might learn something from the other. He endorsed very sincerely the thanks to which Sir Wm. Jones had given expression, and he could only wish that he (Mr. Wood) could have found words the more fitting to express that feeling of thanks.

Mr. Harold J. Plant also supported Sir Wm. Jones in his response to the toast of welcome, remarking that, as a potter, he was charmed by the many beautiful pieces of Copenhagen ware that he saw all around him on the tables. As a potter, he claimed to know some of the difficulties in the production of such pieces, and he congratulated his hosts very heartily on their achievements.

Several other members of the Danish pottery industry rose to identify themselves with the welcome, and voiced their wishes that their visitors might spend a most happy time in Copenhagen. All of these gentlemen, be it noted, addressed the gathering in English, and although it was somewhat difficult at times for the reporter to catch the various turns and phrases, the broad theme could always be readily gathered—"Welcome to Denmark!" and "Here's to one another!"

On Thursday morning, June 8, the party was conveyed from the hotel in automobiles to the Royal Copenhagen Porcelain Works, where Mr. F. Dalgas, the chief administrator, received the party and bade them a hearty welcome. Gathering the whole party around him he gave them a five minutes' address explanatory of what they would see at the "Royal" works. This he prefaced with an apt and well-timed remark. "Last night," he said, "we spoke of feelings which were facts; this morning we shall speak of facts without feelings." After this little lecture, which was a model of concentration, Mr. Dalgas, assisted by the Company's art director, Mr. Christian Joachim; the technical director, Mr. C. A. Poulsen; the head of the mercantile department, Mr. Vigo Scheitel; and the head of the travelling staff, Mr. Emile Bronnum, conveyed the party round the works, and the result was an experience which will long be treasured as a delightful memory.

As Mr. Arthur Hayden so well puts the idea in his "Chats on Royal Copenhagen Porcelain," a presentation copy of which was kindly handed by the directors of the factory to every one of the visitors before leaving the hotel, "It comes as a welcome surprise to the English visitor, educated to other scenes, to find the Royal Porcelain Factory set in a pleasant suburb of the city near the old gardens of the Palace of Frederiksberg." True, the factory chimneys are there, as the author points out, but "there is sunshine in this northern pottery. The courtyard shows a scene such as no other factory in the world can offer," and the writer may add that the interior of the factory is such that, in some portions of it, and particularly the workrooms of the artists, one's first impression is that the view which meets the eye is more suggestive of a con-



Dry Mixing at Copenhagen.

servatory than a workshop. The lady artists were seen to be working in quite an atmosphere of plant and fern life. On the benches and in the windows, foliage and blossom intermingled, and to all who were engaged, work appeared to be a joy quite as much as a duty. It reminded one forcibly of what one had heard from Mr. Dalgas the night before, to the effect that the pottery industry of Denmark was based on the national culture of the Danes, and was indeed part and parcel of it. There was not a single Staffordshire potter who was not impressed by the sight. Just as birds and animals were at home in the courtyard of the pottery, so plant life seemed to have found a thriving atmosphere right inside the pottery workshops.

The artists at Copenhagen are *real* artists. Their work is slow, patient, individual. They realise that their work is dignified and important, and an expression to the outer world of the sentiments of Denmark from within. This is not competitive potting; it is anything but that. The prices asked for the ware can in no sense be compared with English pottery, but neither can its characteristics. Royal Copenhagen ware is just Royal Copenhagen. It grows from within, and is unaffected from without. A stalwart potter from Staffordshire, who is nothing if not an aggressive commercialist, was heard to remark to Mr. Dalgas: "What bothers me is how you manage to get for your wares the prices that you do." "My friend," replied the chief of the Royal Copenhagen Works, "we get for our productions just as much as ever we can." But it is significant that Royal Copenhagen ware can not only demand these high prices, but obtain them also, and the main reason is, that the ware is incomparably fine and challenges competition. A mere copy of it would be futile, for its value lies in its unassuming genuineness.

To describe in detail what the party saw at the Royal Copenhagen Works would be to crib, cabin, and confine ideas that seem altogether too æsthetic. Mr. Arthur Hayden, in winding up the last chapter of his book on the Copenhagen Works, in which he attempted to describe the factory as it exists to-day, must evidently have felt in a similar mood, for he lightly skips over the technical details and comes back swiftly to the idea of a band of artistic potters, trained under happy auspices, whose aims are set steadfastly on art, which is nothing if it be not national. "These are the children of to-morrow," he writes. "New generations will come and go, and new art impulses will beat, as the waves breaking from the Baltic on the little pottery set on a rock and proud in its great achievements....Taking courage in both hands, the potter-sons of Denmark will, in those yet unborn days, carry on the great traditions. There is a great heritage for the sons of the days to come, and looking backward, they will place the laurel wreath on the brow of the masters who, in the old days, and in the present era, have fought the good fight and won the guerdon of praise from potters

in far-off lands, who have paid homage to the art of the Three Blue Lines."

There is only one outstanding fact which the writer will attempt to put on record as a matter of general interest, in the way of technical details concerning the Royal Copenhagen Works, and that is, that we noticed that one important difference in the procedure adopted in the mixing of materials, is the employment at the factory of Danish flint pebbles and Danish boulder flints, in place of the French pebbles that are usually employed by the English china manufacturers. Before leaving for Denmark, the writer was specially asked by a friend in North Staffordshire to make inquiries into this, and to ascertain, if possible, what the experience was. We did so, and ascertained that for the past 20 years the Royal Copenhagen factory has been supplied with these Danish flints by the firm of Scheitel & Co., of Copenhagen. The principals of the Royal Factory consider the Danish flint to be the best in the world, since it originates from the well-known fine Danish writing-chalk formations, and is therefore finer, cleaner, and harder than that which originates from the usual chalk and limestone formations, such as, for instance, those which exist at Dieppe. The Danish flint is, we learned, picked on the shore and partly excavated by machinery from the very extensive layers which have been formed by the sea in the course of thousands of years on the coast of the Danish islands of Moeen and Seeland. The flint-picking industry of Denmark is quite considerable, and of the available picking grounds, Scheitel & Co. appear to control by far the largest. All the flints are washed and sorted by hand before being sold to the pottery manufacturers, and the pebbles, which are graded into six different sizes, are of so hard a nature and of such excellent quality that they are used as crushing media in tube and grinding mills. The point seems to be an important item of information, and it is for this reason that we call attention to it before passing on.

After the inspection of the Royal Porcelain Works a visit was paid to the associated works manufacturing earthenware, viz., the Copenhagen Faience Factory in Smallegade, where considerable interest was evinced in the productions, as well as in the manner of their preparation. Lack of time and space will not permit us to enter into details. We must, therefore, content ourselves by saying that the visit was much enjoyed, and will long be recalled with pleasure. At noon the party was entertained to luncheon in the town showrooms of the Royal Copenhagen Porcelain Factory at 6, Amagertorv—a house that was built in the year 1648. Mr. F. Dalgas presided, and proved a most charming host. In the course of the luncheon Mr. Dalgas said that, on behalf of his colleagues, he had to thank the members of the Ceramic Society for that auspicious visit. "You will have seen this morning," he said, "that at the Royal Factory we very much enjoy art, and you will have seen at the same time that we know what art is worth."

Continuing, he said that, when he came into the factory some 32 years ago, the annual value of the output was 6,000 kr.; the value of the ware that they had made this year had gone up to 60,000 kr. He hoped now that the visitors were about to take leave of the factory and of Copenhagen, that they would carry back with them some pleasant memories of the visit, and that they would be able to return to their homes and tell their friends what they had seen; and remember always that the Copenhagen potters were working specially for their country and in a way that was fair to the potters of the rest of the world. In the capacity of managing director of the two factories which had been visited, and as interpreter for his colleagues, he would like to say that they, on their side, would never forget the honour of that visit, and he would very much like every member of the party to leave his autograph in a special book of distinguished visitors which the factory would be proud to retain.

Sir Wm. Jones, K.B.E., replied on behalf of the Ceramic Society. He said that the two visits which had been made that morning must have had an uplifting influence upon all of them. They had seen that it was the policy of the principals that, whatever the cost might be, nothing must stand in the way of the consistent merit of the ultimate productions. The open-hearted manner in which these high-minded potters had said to men from other countries, engaged in the same industry: "Come in; see just what we do, and how we do it," was something to remember. It was a great lesson the Danish potters had taught them, and he hoped that it would have its reward. The productions which they had seen were beautiful in the extreme. The whole atmosphere of the place was artistic. They could not do otherwise than carry back with them the kindliest thoughts towards their friends, the Copenhagen potters, and all who were associated with them. They hoped sincerely that the days to come would be prosperous, and that the depression, from which the world was at present suffering, would be only of a transient nature, so that the new works, which the potters of Denmark had built during the war, would soon be once again on full time.

At the conclusion of the luncheon each unit of the party was presented with a little souvenir in the shape of a piece of Royal Copenhagen porcelain, and so highly prized were these gifts, and so well looked after, that we did not hear of a single one being broken on the homeward journey.

The same afternoon, a visit was paid by a goodly number of the visitors to the Hedehus Brickworks, situated about twelve miles from Copenhagen, where red building bricks and red roofing tiles were being manufactured by up-to-date machinery on the plastic principle. The inspecting party was conveyed to the works in motor-cars, and after making a tour of the works, was entertained to tea at the house of the general manager, Mr. E. Hartmann,

who, along with his wife and daughters, did everything possible to provide a really homely reception. Meanwhile, other members of the main body, whose recollections of the Royal Porcelain Works were perhaps too soulful to be blunted by such prosaic thoughts as those necessarily associated with machine brick-making, retired to the precincts of the National Yacht Club, there to while away the afternoon under the soothing influence of blue sea and white canvas.

On the last day of the tour the visitors were the guests, during the morning, of the Danish Society of Civil Engineers, who took them for a two-hours' sailing trip through the harbour, which proved both restful and instructive. The Museum of Applied Art was afterwards visited, and at mid-day a luncheon was given by the Chamber of Manufacturers at their headquarters in the Raadhuspladsen. Here Mr. H. P. Prier, the Chairman of the Board, modestly spoke of the smallness of his country as compared with the rest of the Western nations, but claimed that the Danes considered themselves second to none in the warmth of their hospitality to friends. They had endeavoured, he said, in the short space of time at their disposal, to give their visitors a bird's-eye view of the industrial capacity of Denmark, and he hoped that, although the ceramic industry of his country, which they had no doubt come specially to see, was in no sense to be compared with the pottery trade of Great Britain, it would be found to possess certain qualities worthy of admiration and remembrance.

Similar sentiments having been voiced by Prof. Karl Meyer, Mr. H. E. Wood responded, remarking that he could not help noticing how everyone in Denmark was prone to apologise for the smallness of the undertaking with which he happened to be connected. He had noticed this at the Museum of Applied Art that morning, when the Curator was full of apology that his beautiful museum was so diminutive. As a matter of fact, it was distinctly creditable, and something to be proud of. There were many things which they had seen in Denmark which might cause them a feeling of envy. Amongst these must be counted their beautiful surroundings. Upon his return to the Staffordshire Potteries within a few days, he would be looking in vain for the green trees and the blue sky. The concentrated Potteries of North Staffordshire might have their advantages, but they also had their disadvantages, and the lack of a garden atmosphere was one of the latter. They appreciated to the full all that the Danish potters and their associates had done for them. Their methods, although vastly different from the English methods, and in some respects having nothing whatsoever in common, had yet been absorbingly interesting.

Dr. Mellor also spoke on this occasion, for the first time throughout the tour. He said he felt that he could not let that last gathering disperse without expressing his extreme satisfaction at the unqualified success of the trip through the Scandinavian countries. The work which Mr. Odelberg had done had been really brilliant.

One of the main ideas that one formed in Sweden was the wonderful application which the Swedes had made of electricity, and the still more marvellous creation of that electricity from mysteriously hidden natural forces. It made one admire the genius of those who first conceived the idea of transmuting the natural power into such a valuable servant as ordered electricity. They had seen how, from the high-power stations of Sweden, electricity was conveyed for long distances under extremely high tension, to be made use of by local industries up and down the country. Mr. Odelberg had struck the members as being analogous to one of those high-tension wires. Most of the arrangements for the tour had been in his hands, and everyone was intensely satisfied with the final result. It had been intended originally that the tour should be continued from Stockholm to St. Petersburg, but after some correspondence with the authorities, the idea of a Swedish-Russian tour had to be abandoned, owing to the present unsettled state of Russia. He was almost inclined to think, however, that there had been some dispensation of Providence in the matter of the alteration to a Swedish-Danish trip. Messrs. Møller and Michelsen had certainly managed the Danish portion of the trip in a remarkably successful manner. Everywhere the Society had been practically overpowered by a hospitality that was so lavish as to be almost embarrassing. He was sure that everyone must feel specially indebted to Sir Wm. Jones, who had upon so many occasions been called upon at very short notice to transmit their feelings of indebtedness to their numerous hosts. Comparisons were odious and invidious; at the same time, he was almost tempted to say that this particular tour had been the best that the Society had so far engaged in, both as regards hospitality and the sense of comradeship that had existed amongst the members generally. The gratitude they all felt to their Scandinavian friends was inexpressible, and at best their expressions of thanks could but half transmit the feelings which they all entertained as they were now about to take leave of their numerous hosts.

Sir Wm. Jones thanked Dr. Mellor for his reference to himself, remarking that his heart was always in any movement which was calculated to make for the good of the Ceramic Society. He would like just to say that the members of the Society felt that they would never be able to repay adequately their obligation to their Swedish and Danish friends, but he hoped that the time was not far distant when they would be able to extend a return invitation to their present hosts to visit the "Old Country," and he could promise them that, whenever that matter was arranged, they would all do their best to give them a worthy reception and a pleasant and profitable time. Continuing, Sir William said that he, like Mr. Wood, had noticed how all the Danish friends had made some reference or other to the smallness of their country, and some of them to its poverty, but he could at least congratulate them on the

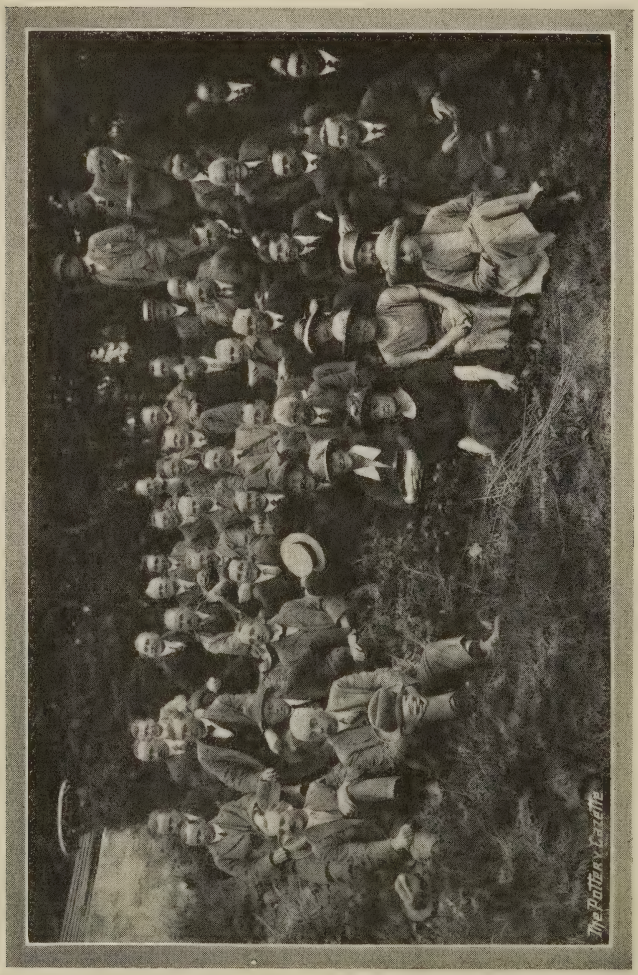
successful manner in which they had camouflaged their poverty. This, of itself, seemed to indicate the business acumen of the Danes. He understood that the Danish Chamber of Manufacturers was closely analogous to the Federation of Bristish Industries, to which he happened to belong, and from which he believed the manufacturers of Great Britain had derived considerable benefit. He was quite sure that the spirit of the age was that manufacturers, instead of isolating themselves, as had been rather the custom of the past, should recognise the advantages of co-operation. He had found that the Federation of British Industries had afforded its members great advantages, through its concerted action in regard to various State encumbrances, as well as in the matter of the amelioration, to some extent, of the incubus of proposed taxation, Possibly the Danish Chamber of Manufacturers had had a similar experience. He noticed that they were suffering from the same sort of depression as we ourselves were encountering at the present time in England, and he was rather afraid that the recovery would be slow. The signs of the times were, however, that we had now passed the worst, and he sincerely hoped that the industries of the respective countries would soon rise Phoenix-like from the ashes, in which they were at present resting, into an atmosphere of assured prosperity.

Mr. Odelberg also acknowledged Dr. Mellor's reference to the part which he had played in the organisation of the tour, and reiterated that it had been the greatest pleasure of his life to meet the members of the English Ceramic Society on Swedish soil. He knew that the natural resources of his country could not but be admired. In a way, Sweden had been abnormally blessed by Nature. It was the duty of Sweden, having been so blessed, to develop those latent resources, and she would have failed grievously as a country if she had not done so. In Denmark, on the other hand, without having been blessed by such resources, it was noticeable that the most wonderful developments had taken place, some of which had fired the enthusiasm of the whole world. As a potter, he felt bound to say that in Sweden the pottery manufacturers had, for the most part, made use of their natural resources in order to make cheap wares for everyday uses. To make it artistic they had had to create a special art department, similar in its constitution to the Art Section of the Ceramic Society in England. In Denmark, however, one found that true art was already a *fait accompli* ; there was no need for an Art Section. The potteries in Denmark were truly "royal" in every respect, and that they had given himself and his English friends a "royal" reception there was not a shadow of doubt. For this he heartily thanked his near neighbours, and joined with them in wishing their visitors a safe and pleasant return home, and the speedy dawn of a prosperous time after the long, dark night of depression in which they were all of them at present engulfed.

After spending the last evening in Copenhagen in the manner

dictated by individual choice, the return journey to England was commenced on Saturday, June 10, via Esjberg and Harwich, London being reached about 9 a.m. the following evening. Although, perhaps, in the 3,000 miles that had been covered in that short period, there had not been a great deal to learn from a pure potting point of view, the knowledge that was gained in a general sense was undoubted, whilst the friendships which had been formed during the tour were something to be valued in the days to come.

[We are indebted to the Editors of *The Pottery Gazette and Glass Trade Review* for the loan of a number of half-tone blocks with which our report is illustrated.]



Dinner to Mr. & Mrs. Odelberg.

ON Thursday, October 5th, 1922, Mr. and Mrs. Odelberg were the guests of honour at a dinner, which had been arranged with a view to providing a suitable opportunity of expressing thanks to them for their kindness and hospitality on the occasion of the Ceramic Society's visit to Sweden in June last. The chair was occupied by Mr. H. E. Wood, the President, and about sixty members were present, the majority of whom had participated in the Swedish and Danish tour.

Sir Wm. J. Jones, who submitted the health of Mr. Odelberg, said he was very proud to be entrusted with this toast to Mr. Axel Odelberg, to whose influence, untiring zeal, and extraordinary organising capacity they could very largely attribute the success of the trip which the Society made to Sweden and Denmark in the early summer. There was no doubt whatever that Mr. Odelberg had gone to enormous trouble to map out with such minuteness the details of that tour, and his splendid English wife, whom he (Sir William) was proud to have sitting beside him at that moment, had assured him, when they were over in Sweden, that for weeks before the arrival of the party her husband had devoted almost the whole of his time laying the plans for their comfort and intellectual benefit. His efforts toward that end had not been in vain, and not a single dissentient voice was likely to be raised as to the complete success and enjoyment which had attended the Scandinavian trip. From the moment that the party landed on Mr. Odelberg's native shore at Gothenburg to the moment when he bade them farewell in the Danish capital, each successive day brought its own special charm and enjoyment. Proceeding, the speaker said that it was scarcely necessary for him to recapitulate the places that were visited, the sights that were seen, the wonderful natural views to which Mr. Odelberg introduced them, and the marvellous engineering and other works that he took them to see and with which he made them acquainted in detail. All these things were much too fresh in the memory to need recounting. But there was one thing he knew they would all like him to say, and that was, how much they had appreciated the great kindness and hospitality which was extended to them by Mrs. Odelberg and her family, and he would like to convey to Mrs. Odelberg their sensible appreciation of the hospitality that was received at the hands of Mr. Odelberg's father, brother, and the family in general. Speaking of families, there was a family spirit that prevailed at Gustafsberg that was quite different from the ordinary atmosphere of an industrial district. It was noticed there that Mr. Odelberg, senior, was looked upon as the chieftain, and his two sons as his deputies. The workpeople at the pottery confided their cares

and interests to them, seeking always the advice of the house of Odelberg. This was admittedly a great testimony to the appreciation in which the Odelberg family was held by those who know them best through living in their midst. He (Sir William) recalled quite vividly the pleasure that Mr. Odelberg, senior, evinced when he showed him some of the things that had been done on the island for the welfare of the community—both old and young—over whom he exercised his beneficent authority.

"From what little I have already said," proceeded Sir William, "you will have gathered that I have a very high appreciation of the character of our friend Mr. Axel Odelberg, our guest of this evening. He has many sterling qualities. Prominent amongst these are his unbounded energy, his foresight, and his wonderful organising ability; but, above all, conspicuous as the great outstanding feature of his character, is his sterling honesty."

At this stage Sir William took the opportunity of presenting to Mr. Odelberg a tangible token of the Society's appreciation of him. The gift took the form of a handsome tureen of 1820 Sheffield plate, mounted on an ebony base, which bore the inscription: "Presented to Mr. and Mrs. Odelberg as a token of appreciation from the members of the Ceramic Society of Great Britain who visited Sweden, in May, 1922." Turning to the recipient, Sir William added: "I am asked by the friends assembled here—members of the Ceramic Society of which you yourself have been an honoured member for some years—to express to you their deep appreciation of the way in which you served them during their recent trip to Scandinavia, and I am requested to ask you graciously to accept this small gift as a mark of such appreciation. Intrinsically its value may not be very great, but we hope and believe that you will value it always as a token of the esteem and affection in which you are held by your brethren in the English ceramic industry."

Turning to Mrs. Odelberg, Sir William asked her acceptance of a suede-bound album, containing a collection of snapshots taken by various amateur photographers during the tour. This bore the inscription, in old English lettering: "To Mrs. Odelberg, as a token of remembrance from the ladies of the Ceramic Society who visited Gustafsberg in June, 1922." He trusted that this gift, small though it was, would bring to Mrs. Odelberg very happy memories of the incidents of the visit that was paid by the Ceramic Society to her home.

Mr. Odelberg, responding, said that it afforded Mrs. Odelberg and himself a most agreeable surprise on their arrival in England to receive the Society's kind invitation. They were both deeply touched, in view of the trouble the members had taken in coming from different parts of the country to entertain them in this manner, and to give them these splendid tokens of friendship. He wanted to assure them that their visit to Sweden afforded them nothing

but pleasure. Their doors were always open to their English friends, and they hailed them with joy, being at any time only too glad to receive visitors from the other side of the water. The more so when members of the Ceramic Society paid them a visit, amongst whom were so many of his old friends and colleagues plodding along with him in the same science, the same industry, the same trade. The visit to Sweden also brought them many good, new friends, as was clearly shown by the presence of so many that night, and the handsome gifts they had bestowed upon them.

"There are many good things in life," continued Mr. Odelberg, "and one of the best of these is friendship. It is like good wine ; it steadily improves with time. It raises us to a higher level, and makes our whole environment more pleasant. It broadens the mind, killing narrow views and selfishness, and brings a great number of other good things in its train. The moments spent with good friends are precious—they form the oasis in the desert. We feel that we are under the palm trees to-night, and we are having a glorious time. This resting place is marked with a milestone, to which we shall always look back with pride and joy."

In conclusion, Mr. Odelberg said he wanted to emphasise that he felt he was amonst fellow-workers, facing very much the same difficulties in the strife of their profession. There was an old saying in his country which he would thus translate : "United burden, half burden ; united pleasure, double pleasure." He had a feeling that this was the motto of the Ceramic Society, and, acting hereupon, he was sure that the English ceramic trade would have a glorious future, of which their many past achievements would be only as shadows cast before, and he hoped that the potters in his own country, who had to some extent collaborated with their English contemporaries, would also have their share. His wife and he raised their glasses in token of mutual good-will and friendship.

Dr. J. W. Mellor, in lighter vein, proposed a toast to "The Ladies," and in paying a tribute to Mrs. Odelberg and the ladies on the other side of the North Sea who, along with her, contributed to make the visit a success, he said that the tour was now sufficiently behind them to enable them to view it in something like true perspective. It could confidently be said that there were nothing but pleasant associations and memories connected with it, and it would require the sweet music of an Orpheus to render adequately the songs of gratitude which rose from all ourhearts. He would not alter a word that he said at Copenhagen, except, perhaps, to modify it by stating that the success of the visit was largely due to the "silent partners" of their hosts. Those who appreciated the many aids that were thus rendered, and who had come under the magnetic spell of the hospitality offered by Mrs. Odelberg, would require no second invitation to rise and drink to the toast.

Mrs. Odelberg replying on behalf of the ladies, said she had had many a task in life, but never such a one as presented itself

to her that evening. She was especially pleased to be present on that occasion in her dear homeland, England, and she would like to say what a pleasure it had been to her husband and herself to receive the Ceramic Society in Sweden. She would like everyone present to understand that, whenever they chanced to be in Sweden again, they would find a very warm and true welcome at Gustafsberg.

Mr. F. Turner proposed "The Ceramic Society." As one of the members of the original North Staffs. Ceramic Society, afterwards The English Ceramic Society, and now The Ceramic Society, he said he felt qualified to speak of the progress which the society had made. The work that it had done and was continuing to do, was of tremendous importance, and the influence that it exerted upon the staple industry of the district was incalculable. Coupling with the toast the name of Mr. H. E. Wood, their president, he said that he had known Mr. Wood for a long time, both in the society and out of it, and he could honestly pay a tribute to his indefatigable zeal, combined with marked ability and tact. He was sure that during Mr. Wood's tenure of the presidency the society would receive considerable help and guidance from him. He raised his glass to the society and to its president, and heartily wished both a successful year.

Mr. H. E. Wood, who met with quite an ovation on rising to respond, assured the society that he would at all events do his best during his year of office. His connection with the Ceramic Society had brought him many friends, and, as Mr. Odelberg had mentioned, friendship was one of the best things in life. Speaking for the society, he could say with confidence that, apart from its meetings and papers, it had stimulated a good deal of talking, both in the Potteries and ouside, upon technical matters, and the extent of the good of this could hardly be estimated. Nowadays there was quite a different feeling amongst competitive potters than formerly. In the old days, when one potter met another, the first question that was usually asked was: "Well, how much have you made?" To-day the question was not so much how much was being made, but *what* was being made, and what was the best way of making it. This had got to be the modern way of looking at things, for they were up against a big proposition at the present time, and their successors might even be up against a bigger proposition still. It would take North Staffordshire all its time to maintain its position as the centre of the potting trade of the world. They were all naturally very proud of the position that they held at present, but they must all do their utmost to hand down the prestige that had been won by the district to those who followed them. Mr. Turner had referred to the fact that the Ceramic Society started as a provincial organisation, that it afterwards assumed a national character, and that now its tentacles had a grip all over the world. Insularity never did anybody any good, and this, he thought, had been clearly shown, not only by the change in the society's

title, but by its attainment of a world-wide membership. It was realised to-day, as it never had been before, that the interests of one country and those of another were intertwined and that they reacted one with the other. As individual potters and as members of the Ceramic Society they must all endeavour to keep this cardinal fact in mind.

Mr. J. Holland (Sheffield) proposed the health of Sir William Jones, and spoke highly of the manner in which Sir William discharged his duties as the spokesman of the party during the Scandinavian tour. The first time that he (Mr. Holland) had the pleasure of meeting Sir William was during the dark days of the country's trouble, when, at the Ministry of Munitions, he devoted his energies and his conspicuous organising capacity to the task of bringing order out of chaos in the refractory materials industry. Sir William was a man of many parts, and his influence upon the Ceramic Society had been most marked, especially upon the refractory materials section. It was difficult to conceive how, among his multitudinous other duties, he found the time to become the president of that section, but from that day the section had grown rapidly and was still continuing to grow. It might almost be said that he had laid the foundation stone of its success. This achievement of Sir William's was followed by the formation of the Refractories Research Association, which was now on its feet, likely to continue for many years and to carry out some very useful and necessary work. As to the part which Sir William played on the occasion of the Scandinavian tour, it was gratifying to think that whilst they had not been able to get Dr. Mellor's Orpheus and his lyre, they were still able to get a worthy substitute in Sir William. It was certain that no one could have discharged the duties of spokesman in an abler manner. During the tour he made seven or more speeches—all of them good and just the thing that was wanted. His style was graceful, and in every case he rose to the occasion as few men could have done. Recognising the many services which Sir William Jones had rendered the Ceramic Society, he was sure there was not a member who would not rise and share enthusiastically in the toast of Sir William's health.

In responding, Sir William Jones, in his accustomed quiet style, returned thanks, remarking that he was quite at a loss to understand why he should have been chosen as the "gas-bag" of the refractory materials section, unless it were that he tried to earn a modest living at gas-making. But in all seriousness he could say that his connection with the manufacturers who formed the backbone of that particular section of the society had been one of the happiest experiences of his life.

Mr. H. J. C. Johnston (the president of the Institute of Clayworkers) proposed "The Press," coupling with it the name of Mr. H. Barrett-Greene, of "The Staffordshire Sentinel," and Mr. H. Townsend, of "The Pottery Gazette," both of whom responded.

Before the members dispersed, Sir William Jones asked the acceptance by Miss Hulme (Dr. Mellor's secretary) of an album of photographs, taken on the Scandinavian trip, as a small but lasting reminder of the tour and in recognition of the work that she had done in connection with the arrangements. Miss Hulme received the album at the hands of Sir Wiliam, and suitable tendered her thanks.

Proceedings.—Session 1922-1923.

The first meeting of the session was a special Open Meeting held in the Central Science School, Stoke-on-Trent, on Thursday, 5th October, 1922. The President, Mr. H. E. Wood, occupied the chair and the attendance was about 120. Mr. A. S. W. Odelberg, of Gustavsberg, Sweden, gave a lecture on: "Some Experiences with the Dörr Mill," and a short discussion followed.

General Meeting held on Monday, 16th October, 1922, in the Central Science School, Stoke-on-Trent. About 60 members were present and the Chairman was Mr. T. Bates. Apologies for absence were received from the President, Major F. H. Wedgwood and Mr. B. J. Allen. A vote of sympathy was passed with the relatives of the late Mr. J. Johnson, of Longton. The following were proposed for membership: Messrs. David Metheven & Sons, Kirkcaldy, Mr. N. P. Ogale and Mr. G. M. Gill. Dr. H. M. Vernon read a paper entitled: "Atmospheric Conditions in Potters' Shops and the Efficiency of Various Types of Drying Stoves," and Messrs. A. Leese, A. Fielding and Dr. Mellor took part in a discussion on the same subject.

General Meeting held in the Central Science School, Stoke-on-Trent, on Monday, 13th November, 1922. Mr. H. E. Wood presided over an attendance of about 50. Nominations for membership were received on behalf of Miss F. A. Royce, Messrs. G. Viggars, R. Bentley and H. Hulse. A paper entitled: "The Gypsum Industry" was read by Mr. A. Brittain, of which he was joint author with Mr. C. Elliott. A short discussion followed, to which Mr. D. F. W. Bishop, Mr. A. Heath and Mr. W. Lindley contributed.

General Meeting held on Monday, 11th December, 1923, in the Central Science School, Stoke-on-Trent. Chairman—The President. About 100 members were present. The following were nominated for membership: Collective: Messrs. B. Laporte Ltd. Student: Mr. W. A. Alldis. Mr. A. Heath gave a paper on "The Crazing of English Earthenware." A long discussion followed in which the following took part: Messrs. H. E. Wood, F. S. Worthington, P. Bailey, B. J. Moore, F. Turner, D. F. W. Bishop, C. D. Grimwade, T. Simpson, A. G. Richardson, F. Carnall and Dr. Mellor.

General Meeting held on Monday, 8th January, 1923. Mr. H. E. Wood presided over an attendance of about 70. The following were proposed for membership: The Massachussetts Institute of Technology, Cambridge, U.S.A., Mr. J. Phillips and Mr. Austin Jones. Mr. John Phillips gave a paper on "Steam Engines and Boilers; how to run them efficiently."

General Meeting held on Monday, 12th February, 1923, in the Central Science School, Stoke-on-Trent. The President occupied the Chair and the attendance was about 60. Nominations for

membership were received on behalf of the following: Collective: The British Cast Iron Research Association. Individual: Messrs. R. V. Widemann, Ritchie Shaw, W. G. Wagner, Mr. B. Ivers, Mr. J. B. Duncan, F. Hayes, N. L. Robertson. Student: Mr. G. Whalley, S. Ash, J. Price and P. Moore. A paper entitled "Notes on the Application of Pyrometers to Ceramic Industries" was given by Mr. C. E. Foster.

General Meeting held on Monday, 12th March, 1923, in the Central Science School, Stoke-on-Trent. The President was the Chairman, the attendance being about 70. A proposal for membership was read on behalf of Mr. Mokiji Ichijo. Dr. A. A. Granger and M. P. Bremont contributed by title: "The so-called Kaolin of Djebel Debar." Mr. Bernard Moore and Dr. J. W. Mellor gave a paper entitled: "The Note Books of Josiah Wedgwood." A discussion followed, in which Mr. H. E. Wood, Major Frank Wedgwood, Dr. Mellor and Mr. A. Audley, took part.

General Meeting held in the Central Science School, Stoke-on-Trent, on Monday, 9th April, 1923. Mr. H. E. Wood presided over an attendance of about 70 members. Mr. A. J. Dale was nominated for membership. Mr. A. Heath and Mr. A. Leese gave a paper: "Notes on Black and Grey Flints," and the President, Dr. J. W. Mellor, Mr. A. J. Richardson and Mr. W. E. Goodwin discussed the same. The meeting then took the form of a Question Box, the following questions being discussed. Are silica bricks suitable for pottery ovens and kilns in positions such as immediately over the bags, midfeather, etc.? Answered by Mr. S. S. Riley. What is the cause of frizzling in enamel red on sample plate? Answered by Mr. H. E. Wood and discussed by Mr. J. Miles. What is the best method of removing brown discolorations (breezed) from large pieces of biscuit ware? Answered by Mr. W. Lindley and discussed by Messrs. B. Moore and H. E. Wood. What is the best surface factor for milled materials in an (1) Earthenware; (2) China; (3) Sanitary; (4) Tile body. Answered by Mr. Bernard Moore. Discussed by Mr. A. G. Richardson and Mr. W. Lindley. What is the cause of the scum or deposits, sometimes white and sometimes yellow in colour, which appears after the biscuit fire on the edges of bowls and occasionally on the edges of plates? Answered by Mr. B. J. Moore. What is the cause of blistering of certain samples of Cornish Stone? Answered by Mr. J. A. Callcott.

Annual Meeting held on Monday, 30th April, 1923, in the Central Science School, Stoke-on-Trent. Chairman: The President. 28 members were present. The following were nominated for membership of the Society: Mr. J. Mear, Mr. L. Holdcroft and Mr. A. E. Hubbard. Mr. H. E. Wood gave his Presidential Address. The Committee's report dealing with alterations regarding the election of officers was adopted. The Council's Annual Report was read and adopted. Officers for the session 1923-24 were elected and a vote of thanks was passed to all who had held office during the past session.

Proceedings of the Refractory Materials Section of The Ceramic Society.

General Meeting held on the 3rd October, 1922, in the Chamber of Commerce, 95, New Street, Birmingham. The meeting opened with a discussion on "Bricks for Coke Ovens," in which the following took part: Messrs. A. H. Middleton; G. M. Gill; T. Biddulph-Smith; W. J. Rees; H. J. C. Johnston; J. W. Lee; G. W. Bradley; E. M. Myers; Sir Wm. Jones and Col. C. W. Thomas. The following papers were read: "Technical Education in the Refractories Industry" by Mr. G. W. Hefford; "Some New Forms of Kilns" by Sir A. Duckham; "The Grading of Silica Bricks" by Mr. P. B. Robinson, M. Met., and Mr. W. J. Rees, B.Sc.; "The Reversible Thermal Expansion of Silica" by Mr. C. H. Fenner. In the evening a Dinner was held at the Grand Hotel, Birmingham, Lt.-Col. C. W. Thomas, presiding.

Sir Wm. Jones, in proposing a toast to "The Visitors" said: "The policy of our Society, as you know, has been for some years past, to make our Spring Meeting the occasion of a visit to some distant part, and to make of each Autumn Meeting a sort of home function. The Autumn Meeting we have usually held in one or another of the industrial centres of Great Britain, whilst on the occasion of our Spring Meeting we have gone farther afield and visited places of interest in other countries. But wherever we go we always seem to receive the most extraordinary hospitality from the leaders of industry and education. I rejoice to think that we have with us to-night, as on so many occasions in the past, a number of visitors of some distinction. We have with us Prof. T. Turner, of the University of Birmingham; Mr. E. M. Myers, the President of the Coke Oven Managers' Association; and my very good friend Mr. Axel Odelberg, who, I think, is an old member of our Society, yet must in some senses still be regarded as a visitor—in one sense at all events; it is very seldom that we have the pleasure of seeing him at such serious meetings as those of the Refractory Materials Section. We are delighted always to have gentlemen such as these at our business meetings, and to have the advantage of their experience in assisting us to arrive at correct conclusions in respect of those subjects that we endeavour to discuss faithfully and intelligently. We are more delighted still that we happen to have them with us at a festive board such as this. I desire to couple with the toast the name of Mr. Myers, the President of the Coke Oven Managers' Association, who takes the liveliest interest at all times in the proceedings

and welfare of this Society and who, I may say incidentally, has shown me on numerous occasions the greatest possible kindness when I have had occasion to visit the Shelton works, with which he is connected."

MR. MYERS, responding, said: "It is true that at the present time I have the privilege and pleasure of being the President of the Coke-oven Managers' Association, but fortunately, I also happen to be a member of the Ceramic Society, and, therefore, I do not know whether I ought really to be considered as a visitor. I would, however, like to say one thing which I did not say at the meeting this morning, and that is, I would like to enlighten some of my friends present who may not know what the coke-oven industry really implies. I claim—and I think I am right in claiming—that the coke oven industry is the great key industry which stands between the collieries and the metallurgical industries.

"It was said during the war that if the coke-ovens of the Central Empires could only be destroyed, the war would be over within a week, and I think Sir Wm. Jones will agree that that is a statement not very far from the truth. But the coke-oven industry of this country, also, has rapidly developed during the past 20 years, and its development is not only due to the fact that, as its very name implies, it stands for the manufacture of coke, but also for an enormous variety of by-products which are recovered during the manufacture of that coke.

In America—a country about which we have heard a good deal to-day—they have relegated their coke-oven problems to engineers, who have evolved a very highly successful article, and I think we, in this country, are gradually waking up to the fact that we, also, must entrust our coke-oven problems to engineers if we are to evolve a similarly successful product.

Now there is a very intimate connection between the coke-oven industry and the refractory materials industry, inasmuch as coke-ovens must necessarily be built of refractory materials. I have had a fairly long experience of by-product coking, dating back to the end of 1903, and I have seen during the period between then and now a tremendous improvement and a tremendous succession of developments in connection with the industry. I remember that at one time coke-ovens were looked upon very largely as mystery plants, and that it was only possible to work such plants by importing German technical people to run them. I remember also very vividly seeing a coke-oven plant started up for the first time by a German technical man, and the amount of fuss and bother and the waving of arms with which the process was accompanied made me feel that it really must be a terrible thing to run a coke-oven plant. In later years, however, I have come to change my ideas, and have started up plants myself—with very much less waving of arms than I saw back in the years 1903-4.

I have been fortunate enough to have the advantage of seeing coke-oven plants operating in numerous parts of this country, as well as in America, France, Germany and Belgium, and I think, after having seen those plants, I can say that it is possible for us to equal anything that has been done in these other countries if only we put our minds to it. The problems before this industry are not yet all solved. There is plenty of room for research, especially in the direction that we have been discussing to-day—refractories.

Most of you have heard the discussion which took place this morning, and even after hearing that discussion, you will probably agree with me when I say that finality in the matter of the product that is necessary for the building of coke-ovens has not yet been reached. Therefore, it behoves each one of us—and especially those people who are connected with the refractory materials industry—to endeavour to evolve an article which will enable this great key industry—the coking industry—to attain to such a position as will enable it to hold that sway which shall not only make it a profitable industry to run commercially in connection with the coal industry, but shall also make it an indispensable adjunct to the great iron and steel trades of this country.

Not only does the refractory materials industry require this research work to be carried on, but the problems of the by-product side of the question require thought and elucidation. There are many problems still to be considered, although one of the greatest is, no doubt, the question of refractories, because without a perfect oven or a perfect refractory material used in the construction of an oven, the by-products would be non-existent.

Speaking on behalf of my colleagues of the Coke-Oven Managers' Association, may I say how very much indebted we have been to the Ceramic Society for giving us an opportunity of joining with them in the discussion on this very important subject. I strongly agree with the President's remarks this morning when he said that discussions of this kind with the representatives of other industries who use your refractory materials cannot help but be highly beneficial to both you as producers and the industries to which you look to consume your materials. I would like to take the opportunity of expressing my sincere thanks to Sir Wm. Jones for the very cordial way in which he proposed the toast and to you, generally, for the very hearty way in which you have received it."

Mr. A. S. W. Odelberg, who also responded for the visitors, said: "It is the first time that I have had the pleasure of being present at a meeting of your Refractory Materials Section in your own country, and I may say that I have been very much impressed by the research work which it is clear is being carried out by this Section. I have some sort of idea that there is in my own country an institution which carries out research on something like similar

lines for a variety of industries. But I may say that I have been more than impressed by the wonderful way in which you seem to carry through matters here specially connected with your particular trade. The cordial spirit that I have found existing amongst you seems to me wonderful. I would certainly like to see ceramic research more seriously developed in my own country. So far, I fear no such work has been done in a really official manner. There was established some years ago an Academy of Engineers to carry out research work on general lines, but so far as I know, they have not taken up specially and particularly the ceramic trade. I would also like to see more work of this kind carried out mutually between my country and England. On behalf of the visitors I thank you cordially for your reception of the toast so kindly proposed by Sir Wm. Jones."

PROF. T. TURNER (University of Birmingham), who proposed "The Refractory Materials Section of the Ceramic Society," said: "Few people, I am afraid, realise the extreme importance of the ceramic industries to human progress. If one looks around in the world, however, one will not be long in seeing in how many forms and for what very different purposes clay in one form or another is employed. If we consider the matter first of all archæologically, there is no better indication of the condition of a people or the progress that they attained in their industries than the remains of their pottery that we find in examining the places where they lived. And if we go back into history, we find that some of the very earliest of the world's history is inscribed upon clay tablets which were baked. Of these many thousands are now to be found in our museums, giving us accounts not only of what their kings and nobles did, but even giving us particulars of their commercial transactions and their domestic correspondence, which is preserved to us permanently in this baked clay. Many such remains have been found in connection, for instance, with ancient Chaldea, Assyria and Egypt. The old Babylonians and the Egyptians, unfortunately, did not bake their clay bricks and the result has been that these bricks have gradually crumbled into dust, and, consequently, little or nothing remains of the great erections which these nations projected and carried out. All through the centuries that have passed since these early days to which I have referred, the ceramic industries have supplied us with articles of beauty and utility for daily use.

Now, clay is a very complex substance; it varies very much in its composition and it undergoes remarkable changes during the process of working and firing. It is necessary, therefore, that we should have precise scientific knowledge in connection with the development of the industry. We have seen how other countries have developed that scientific knowledge, and it is for us to see that we are not left behind in the race. I am glad to

know that this particular Section of the Ceramic Society has done such excellent work, especially during the past few years. Research, during recent years, has increased very considerably in complexity and breadth. Originally, the chemists and alchemists of industry studied only the properties of elements; as time proceeded the attention of the chemists was directed to bodies less simple, and progressively they have tackled materials of gradually increasing complexity, thereby widely extending the scope of human knowledge of chemistry and the properties of the materials which have been handled.

Clay, we have said, is a very complex substance. Take the analysis of a clay. How complex it is! You are dealing with materials that are not soluble in water; which are very difficult to decompose, and the principal changes in which take place usually only at high temperatures. You are dealing not with one element, but with many, and one by one we must add various substances in order to check these properties which we desire to record. It is necessary, therefore, that we should have scientific knowledge of a very high character if we are to understand what takes place in the mixing and the baking of clay, and if we are to attempt to provide materials which have to withstand a very high temperature.

How badly off we should be without clay products of the right kind! We should, for instance, have no regenerative furnaces, no efficient coke-ovens, certainly no electrical furnaces, and many of the characteristic products of recent years would not have been possible to us. I have in mind particularly some of the alloy steels which are of such enormous importance to modern industry.

Much has been done in connection with your Society in the development of knowledge and of research, and it has been a great pleasure to me, having been connected with the Stoke school from its earliest days, to notice this. I recall the fact that the late Mr. A. S. Bolton came to me one day at my office and asked my opinion about a piece of land of about three acres closely adjoining Stoke-on-Trent station and the North Stafford Hotel, on which he had obtained an option with a view to reserving a site for a North Staffordshire College. I gave my opinion, and the site, as you all know, has been utilised. Twenty-five years have now passed since that conversation took place, and since the death of our respected benefactor, Stoke-on-Trent has assumed a leading position in this country from the aspect of technical education, and is now recognised in many parts of the world as being a centre for research of the highest grade.

I am very glad to hear, also, that classes are now being started in South Staffordshire. I ventured, something more than 30 years ago, to suggest that such classes should be held, but there were than difficulties in the way. I ventured to suggest at the time that difficulties were made to be overcome, but it took some

time to overcome them. However, these classes have now been begun. I have not yet had an opportunity of visiting the laboratory and I cannot, therefore, speak from personal knowledge of what has been done, but I do wish the very greatest success to these classes, because I feel that they are of such extreme importance to the district.

The deliberations of your Society and your "TRANSACTIONS" have been of extremely great value. Your Council has been good enough to send for the use of our library at the University copies of your "TRANSACTIONS" as they have been issued from time to time, and I have read them with interest and admiration. I am satisfied from a perusal of each volume that very excellent work is being done, and in the knowledge of this I can with the very greatest confidence commend to you that part of the toast "The Refractory Materials Section of the Ceramic Society."

It is my privilege and pleasure also to connect with this toast the name of Lt.-Col. Thomas, your President. I remember him as a student at the Mason College in the old days when I was a young demonstrator and he was a young student, and we have kept up a measure of friendship ever since, limited only by the fact that we live at a distance and do not see each other as often as I, at all events, would like. Col. Thomas has been extremely kind to us from the University point of view in allowing our students on many occasions to visit his works, and he has always taken the greatest possible interest in such a visit. Our men at the University have come to look up to Col. Thomas, more of less, as a father of the fireclay industry. He was good enough some years ago to say that he would like our men to know something of what was being done in Germany and other parts of the world, as well as what was being done in England, in the interests of the refractory materials industry. And he desired me to accept on behalf of the Department's library a copy of Cramer's "*Researches on Fireclay*." We referred to that book time after time for some years. Then the war came, and the men were turned out of the University in order that it might be converted into a hospital. During the use of the Department as a hospital that book, unfortunately, disappeared. I do not know what use is being made of it to-day. But I fancy Col. Thomas really gave it to a wounded soldier. We will hope that it is doing him some real good. At all events, we are very grateful to Col. Thomas for the kind assistance that we have always received from him, and as I know that you appreciate his work as President of your section, it is not a difficult matter for me to ask you heartily to accord the toast which I have to present—the Refractory Materials Section of the Ceramic Society, coupled with the name of Col. C. W. Thomas, of Stourbridge."

COL. THOMAS, responding, said: "Prof. Turner was good enough to refer to a date, I will not say how long ago, when I, more or less, sat at his feet and imbibed my first instruction in chemistry and kindred work. I can assure you that I have not

forgotten those days, even if they are so long ago. Indeed, I have often thought about them, particularly of more recent days. That period of my life represented the first beginnings of any tendency on my part to investigate things, and I do not hesitate to say that it is a tendency which has grown upon me more markedly as the years have gone by. I must confess that nowadays the extent to which one may acquire knowledge seems to open out a wider vista almost every week. One or two of the speakers to-day have referred to some branches in which we are expected, apparently, to know a great deal more than we already know, and to be able to do a great deal more than, up to the present, we have thought we could.

One of the chief attractions, I have always thought, of the Ceramic Society has been its catholic outlook. It has touched so many activities; so many branches of industry and so many lines of research and enquiry have been opened out to us when we have read through the various papers in the "TRANSACTIONS." But I may, perhaps, be forgiven if I think that for general utility to the kindred industries of the country, the lines of possible development which this particular Section of the Ceramic Society seems to open out are fully equal to those that the parent branch of the Society is able to offer. I was almost going to say they are more important still.

We have heard to-night of the importance of the coking industry and of the metallurgical industry, and we have been told that both of these industries are to a very large extent dependent upon the refractories industry, and I may perhaps be forgiven for suggesting in that connection, that I should be very glad to see a larger membership and a more active interest in the work of the British Refractories Association, particularly in connection with those whose lot it is—I was almost on the point of saying whose *happy* lot it is, but perhaps it may be wise for me not to be so bold—to use refractory materials. Sir Wm. Jones will bear me out, I think, when I say that the formation of the British Refractories Research Association was the direct outcome of this particular Section of the Ceramic Society. He will further bear me out, I am quite sure, when I say that the interest that has been taken by the manufacturers of refractories, although this may not have been by any means as marked as one might have liked it to be, has never been greater than that which has been shown by those who are the users of the refractories. I think it is a matter for serious consideration, and a matter to which we all ought to address ourselves, in order that we may awaken a wider interest amongst the users of refractories in the activities of this particular branch of the Ceramic Society, and more particularly still of the Research Association which has grown from it.

I make no excuse for going back to the question of research, although I spoke at considerable length about this at our Autumn

meeting last year, and although I have referred to it on so many other occasions. I repeat I make no excuse for my action because I regard the necessity for research as one of the most vital things of the refractory materials industry at the present time. The discussion that we had this morning on coke-oven bricks—silica bricks *versus* others—is quite sufficient pretext for me to refer to the matter here. If you consider what the industry has to do, I think you will agree with me that the scope it affords for research is greater than exists in many other industries. We are in this position—fortunately or unfortunately. The majority of the fireclay manufacturers mine their own raw clay and from it turn out the finished product. The whole process from start to finish takes place in our own hands, in our own works. Now, in other more fortunate industries, the manufacturers are in a position of being able to go into the market with a specification and buy pretty much the exact material which they require. We, on the contrary, have to grope about in the dark for our material. We are lucky if we find it, and we are still more lucky if it does not change within the next few yards. From start to finish, from the time we commence sinking the pit to the time the finished goods leave our works, we have to be constantly on the watch to see that the material, whether in the process of being mined or in the processes of working up, is what we require it to be for the particular form of refractory product that we are aiming, for the time being, at making. All the way through, at every step of the process, there is a possibility of the ultimate products being spoiled by a comparatively trivial amount of inattention on the part of one or another worker—it may be the temperer who mixes the clay for the moulder, and who makes it either a little too stiff or a little too soft, which leads to various contractions which have been spoken about to-day, or it may be the burner, who fires it either too much or, as more usually happens, too little, and you get the varying sizes which have also been alluded to. Other faults there are which may develop as the result of quite a small lack of attention or of precision in the manufacturing processes.

I am fairly sure that I am right when I say that we not only require research into the question of the body that we are to use in the make-up of articles for any particular purpose, but we also need instruction, and still more instruction, in the way in which it is to be made, the way in which it is to be burned, and so on. We want also some amount of research into the methods by which our people are to be trained in order to give a better quality of work in turning our the goods which they are already engaged in making.

Now I have been interested for a long time in the question of technical education—more particularly as applied to the refractory materials industry, and I am bound to confess that at the present time I do not see exactly how we are going to devise any scheme of technical education which will produce a perfect and

skilled worker in our particular industries—a worker of that calibre that one would like to see. For the simple reason that we have to start upon two classes of raw material. There is first of all the man who has been engaged on the works for some years—perhaps many years—and who has got into a groove, who has discovered methods of his own and has got into a state of mind when it is practically impossible to switch him into a better path. Secondly, we have to take an extremely crude raw material in the shape of the youngsters just leaving school who come into the industry and who, as Mr. Hefford hinted this morning, in the course of their education have, I am afraid, not always succeeded in achieving the standard of being able to add up correctly, much less to work out a simple formula, and whom it is impossible to place in a technical school and put through any form of instruction, simply because they have not already acquired the foundation for mental training upon which one might build. I have had it suggested to me at various times that some form of apprenticeship would be an improvement. I do not know. Sometimes I have thought it would; at other times I have been inclined to doubt it. But something certainly wants doing to awaken in the minds of those who are responsible for the working out of the products a greater interest, and greater attention to precision of working.

The day has now gone by when variations of a quarter of an inch in the size of a block will be overlooked by one's customer. I have known more than one instance where a specification has fixed a limit of one-sixteenth of an inch. We have the Gas Engineers' Specification of something like one or two per cent. of after-contraction; and the whole tendency is towards greater precision in the matter of size, and greater trueness of shape. The Glass Industry is calling out simultaneously for rectangular glass furnace blocks which shall be perfectly plain on every face, which shall have the corners intact, in which there shall be no cracks, no after-contraction, no, anything! Various other industries are calling out for higher temperature resistances to slag action, dust action, cutting action of furnace gases—all sorts of things. The day when a man made a firebrick and someone else bought it and no-one else asked any questions of either of them has gone—no doubt for ever.

I have ventured these remarks because I want to hammer once more the same nail. I want to rivet your attention upon the point that research is an important factor to this industry, and if I am not mistaken it is more important here than in many other industries which have much more flourishing Associations, because we have to remember the results and consequences which depend upon the quality of the product which we turn out. We have been told of coke ovens which have had lives of six months, nine months, twelve years, forty years—I almost tremble to contemplate it.

But one thing is certain. The more or less haphazard methods of manufacture have got to go, and the future is going to be in the hands of those who are prepared to turn out what practically amounts to a guaranteed product. Well, most of you who are here know sufficient of the industry to realise that that is impossible unless existing methods are radically altered, and more particularly unless our control of the methods becomes much more precise and exact.

The results which we are striving for can only be arrived at in two ways: we must first of all, by means of research, find out just what is wanted—and, by the way, I envied Sir Arthur Duckham this morning when he said that if anyone was prepared to come forward and say just what was wanted he was prepared to give it to him. For my own part, I would *do my best* to give it to him, but under present circumstances I would not be prepared to guarantee. As I say, we have got to get to know by research more and more what is wanted. We have then got to get past the stage when the user cannot tell us much about what he wants, or even in some cases what is likely to happen to the goods when placed in his own furnaces. We are gradually getting past all this, and I hope towards a stage when, knowing what is required in a given furnace, of a given type of refractory, we shall be able to work out a prescription and to say "Such and such a body is necessary, and the prescription for that body is such and such materials and such and such heat treatment; and there you have it." And having once got to that stage, we manufacturers of refractories will have to possess an executive staff who have had a training on such scientific lines that they are able to think in corresponding terms and to see that those under them who have the actual making and finishing of the goods to carry out, work within the certain narrow and prescribed limits allotted to them.

Probably I shall not be here to see the results attained, because I do not think it will come so speedily as all that. As Prof. Turner hinted, my association with the industry runs back almost forty years, and I have seen very great changes in the working conditions of the industry during that time—more particularly in recent years. I may not live to see such an ideal state of things as I have outlined, but I am quite convinced that as the years go by we shall all find that we have got to work within much narrower limits, and on these lines I want to impress upon you all once more the vital importance to the industry of paying serious attention to systematic and organised research, and to the systematic and organised training on scientific lines of those who have got to conduct the industry in the future. I want you to make a resolve to take action more and more on these lines in the future."

Mr. H. J. C. Johnston proposed "The University of Birmingham," coupling with the toast the name of Mr. G. W. Hefford, who suitable responded.

The function then terminated.

The meeting was continued on Wednesday, 4th October, when the following papers were read: "The Behaviour of Clays on Heating" by Mr. H. S. Houldsworth, B.Sc., and Prof. J. W. Cobb; "Some Changes taking place in the low Temperature Burning of Stourbridge Fireclays" by Mr. C. E. Moore; "An Examination of Refractories by the Oxy-Hydrogen Blowpipe" by Mr. A. L. Curtis; "Graphic Methods of determining the stresses in Furnace Walls owing to Temperature differences" by Prof. C. H. Lees, D.Sc., F.R.S.; "X-Radiogram of Kaolinite and the Thermal Decomposition of Clay" by Prof. W. H. Bragg, D.Sc., and J. W. Mellor, D.Sc. The afternoon was devoted to the business of the Society. Mr. G. H. Timmis resigned from the Council owing to pressure of other business, and Mr. C. R. L. Threlfall was appointed in his place. Nominations for membership were received from the following: Messrs. Guy Harris; M. M. Sur; A. S. Newsom; F. Salt; Theodore L. Wenger; A. W. Bennett; C. E. Jackson; Detroit Public Library; Emil S. Sieurin; G. W. son Cronquist; Fernando F. Ladrera; P. B. Robinson; A. Lomas; Brittains Ltd.; T. G. Green & Co.; The Pottery Managers' & Officials Association; Aktiebolaget Ifö Chamotte & Kaolinverk. A vote of thanks to Col. C. W. Thomas and Mr. N. S. Bache was passed for the excellent arrangements they had made for the meeting.

General Meeting held on the 3rd May, 1923, in the Town Hall, Bournemouth. The meeting opened with a paper by Mr. H. Dewey on "The Geology of the Bournemouth District." This was followed by a lecture, given by Mr. A. S. E. Ackermann, B.Sc., on "The Physical Properties of Clays," after which the following papers were read: "The Use of Refractory Materials in Gas Works" by Mr. G. M. Gill: "Note on the Abrasion of Fireclay Materials" by Mr. W. C. Hancock B.A. The following papers were communicated by title: "Notes on the Mineralogy of Ball Clays" by Mr. A. Scott, D.Sc., M.A.; "The Behaviour of Clays, Bauxites, etc., on Heating" by Prof. J. W. Cobb and Mr. H. S. Houldsworth. In the afternoon the members visited the clay pits of Messrs. Pike Bros., Wareham. Members and friends dined together at the Grand Hotel Bournemouth.

On Friday, 4th May, a business meeting of the Society was held and a new scheme for the election of officers was adopted. Mr. J. Holland was elected President of the Society for the year 1923-24, and a vote of thanks was passed to the retiring President, Col. C. W. Thomas. It was arranged that the Autumn meeting should be held at Chester, and that the foreign trip, early in 1924, should be to Italy. A vote of thanks was passed to the Corporation of Bournemouth for their kindness in placing rooms at the disposal of the Society, also to the Local Committee, the Local Secretary (Mr. F. Vickers Crawshaw) and the proprietors of the works of the South Western Pottery, Messrs. Sharpe, Jones & Co., and Mr. L.

G. Pike. The following papers were read: "Dolomite" by Dr. L. M. Parsons; "The Manufacture of Refractories in America" by Mr. A. F. Greaves-Walker. During the afternoon members visited the works of Messrs. Sharpe, Jones & Co., Ltd., Bourne Valley Pottery, and Messrs. T. Wragg & Sons, Ltd., after which the meeting terminated.

The Department of Scientific and Industrial Research.

The Lord President of the Council has accepted with much regret the resignation of Sir George Beilby, LL.D., F.R.S., after nearly seven years' voluntary service as Director of Fuel Research and Chairman of the Fuel Research Board under the Department of Scientific and Industrial Research. The Board was established in 1917, to investigate the nature, preparation and utilisation of fuel of all kinds.

The Lord President has appointed Mr. C. H. Lander, D.Sc., M.I.Mech.E., A.M. Inst. C.E. to be Director of Fuel Research, and Sir Richard Threlfall, K.B.E., F.R.S., a present member of the Board, to be Chairman. The Hon. Sir Charles Parsons, K.C.B., F.R.S. will continue his membership of the Board for a further period. Sir George Beilby retains his membership of the Advisory Council of the Department, and has consented to act as Honorary Adviser to the Board.

The following gentlemen have accepted appointment as additional members of the Board:—Mr. R. A. Burrows, Sir John Cadman, K.C.M.G., D.Sc., Dr. Charles Carpenter, C.B.E., D.Sc., Mr. Samuel Tagg, Prof. Sir James Walker, D.Sc., LL.D., F.R.S., Prof. R. V. Wheeler, D.Sc.

Council's Annual Report.

Gentlemen,

In this our 22nd Annual Report there are few outstanding incidents to record, but the closing Session has been quite satisfactory.

The membership at present stands as follows:

Honorary Members	5
Ordinary .. .. (including both collective and individual members).	691
Student Members	33

Papers on subjects covering a wide range have been read at the monthly meetings at Stoke-on-Trent. The good attendance at these meetings has been maintained.

Since the last Annual meeting about 50 members have made a trip to Sweden and Denmark, during which the Spring Meeting of the Refractory Materials Section was held, the Autumn Meeting being held in Birmingham.

We wish to acknowledge our obligations to Mr. A. S. W. Odelberg, who made all the arrangements for our visit to Sweden, and we wish to thank the Governors of the Central School of Science and Technology for the use of rooms.

Mr. HENRY WATKIN.

WITH deep regret we have to record the death of Mr. Henry Watkin, of Porthill, the managing director of the firm of Macintyre & Co., Ltd., Washington Works, Burslem, who was one of the founder members of the Ceramic Society and one of our Vice-Presidents. Until a few years ago he was often to be seen at at our meetings, and he worthily contributed to numerous discussions. The sad event occurred on Saturday, July 7th, at Trentham.

The tragic news of Mr. Watkin's death was received in the Potteries with the sincerest grief, for he was very well known and everywhere respected. He had had a lifelong connection with the pottery trade, which will be readily appreciated when we state that he was at one time with the firm of Pinder, Bourne & Co., Burslem—that is to say, before that concern was taken over by Doulton & Co., Ltd.

For forty years before his death Mr. Watkin had been connected with the firm of Macintyre & Co., Ltd., and he was not only a practical potter but a real technician. At one time he acted as an instructor of pottery classes in North Staffordshire, and his work in this connection was later carried on by the late Mr. William Jackson. Thus, it was the work of these gentlemen which ultimately led up to the provision of the Central School of Science and Technology, and the present ambitious curriculum for pottery students

Mr. Watkin was also responsible for the invention of a heat-recording contrivance for pottery ovens, which he covered by patent rights.

Under Mr. Watkin's capable administration the business of Macintyre & Co., Ltd., was very successfully developed, and they rose to fame in connection with the special technical branch of pottery production which they took up so ardently, viz., the production of electrical specialities, door furniture, etc. By his death the Potteries district is decidedly the poorer, but he has left his foot-prints well impressed on the industry which it was his pleasure and honour to serve.

H.T.

Dr. J. E. STEAD.

WE regret to announce the death of Dr. J. E. Stead. During the past half century, his name has been very familiar in practically all branches of metallurgical science, and the reputation which he has obtained as a result of his research work is second to none in the various branches with which he was concerned. Although trained as an analytical chemist and working in the Middlesborough District in such a capacity for much of his life, his research work at an early stage extended beyond analytical practice, and involved metallurgical problems of a very varied nature. Not only was he concerned in the development of the iron and steel industry, especially with regard to the basic bessemer process, but he also touched many of the non-ferrous metals in his research work. This work involved various processes employed in the manufacture of the metals and also many problems regarding the structure and properties of the finished materials. Amongst the latter may be mentioned his numerous papers on the crystallography of the different metals, while amongst the former he was one of the pioneers in the investigation of slags. In fact, he may be regarded as one of the most skilful experimenters in the domain of applied microscopy in which he was not only responsible for the development of new methods, but he also utilized, very skilfully, already existing technique.

Dr. Stead will long be remembered for the very encouraging assistance he was always willing to render other persons working in similar fields. His generosity in this respect has been gratefully recognised by many metallurgists in the past.

Although his published work in connection with the activities of this Society was slight, the members were greatly indebted to him for much kindness in connection with the organization of certain meetings, and for the past six years he has been a Vice-President of the Refractory Materials Section.

He will be much missed by those who knew him personally, while, so far as metallurgical science is concerned, his death leaves a gap which will be very difficult to fill.

THE CERAMIC SOCIETY.

Honorary Members.

THE PRESIDENT OF THE AMERICAN CERAMIC SOCIETY.
A. F. GREAVES WALKER, Pittsburgh, Penn.

H. le CHATELIER, 75, Rue Notre Dame des Champs, Paris.

Prof. Comm. ORAZIO REBUFFAT, via S. Maria ad Agnone 18, Naples, Italy.

Prof. W. VERNADSKY, Russian Academy of Science, Geological and Mineralogical Museum, Petrograd, Russia.

Dr. A. GRANGER, 212, Boulevard Pereire, Paris, XVII.

Dr. J. W. MELLOR, Sandon House, Regent Street, Stoke-on-Trent.

Ordinary Members.

(*The asterisk*(*) *represents the members who have published papers in the Transactions.*)

*ACTON, T. ARTHUR, The Chalet, Minera, near Wrexham ..	(1916-17)
ADAMS, A. G., c/o Scotia Bank Fireclay Co., Ltd, Burslem, Stoke-on-Trent	(1911-12)
ADAMS, A. J., Scotswood Fireclay Works, Scotswood-on-Tyne	(1917-18)
ADAMS, W., & SONS, Greenfields Pottery, Tunstall.. ..	(1914-15)
ADAMS, JOHN, A.R.C.A., Encaustic Tile Works, Poole ..	(1918-19)
ADAMS, C. N., The Pinfold, Basford Park, Stoke-on-Trent ..	(1920-21)
*ADDERLEY, J. R., c/o. E. J. & J. Pearson, Stourbridge ..	(1915-16)
ADMINISTRATEUR DIRECTEUR GENERAL, de la Cie. des Forges et Acieries de la Marine, et d'Homecourt, 72, Rue de la Rochefoucauld, Paris	(1918-19)
AKTIEBOLAGET, IFÖ CHAMOTTE KAOLINVERK, Bromölla, Sweden	(1922-23)
ALLAN, J. B., David Colville & Sons, Motherwell	(1917-18)
*ALLEN, B. J., Llangladune, Caverswall Lane, Blythe Bridge, Stoke-on-Trent	(1905-06)
ALLEN, & SON, Ltd., Halifax	(1916-17)
ALLETSON, H. J., Castle Firebrick Co., Northop, Flint ..	(1916-17)
ALLMAN, J. B., 11, Newcastle Road, Shelton, Stoke-on-Trent	(1920-21)
ALLMAN, GEORGE, 69, Stanley Street, Tunstall, Stoke-on-Trent	(1920-21)
ALMSTRÖM, H., Rörstrand, Stockholm	(1912-13)
ALMSTRÖM, K., Rörstrand, Stockholm	(1912-13)
AMERICAN LEAD PENCIL Co., 502, Willow Avenue, Hoboken, N.J. (Lower Clapton Road, London, E. 5.) ..	(1920-21)
AMISON, W., 102, Uttoxeter Road, Longton	(1920-21)
ANDERSON, W., c/o Anderson, Levanti & Co., 471, Alsina, Buenos Aires, Argentine	(1917-18)
ANDREW, J. H., D.Sc., Royal Technical College, Glasgow ..	(1921-22)

ARLEUX, MOREL D', Vierzon (Cher), France .. .. (1920-21)
*AUDLEY, J. A., B.Sc., F.I.C., Cliff Bank House, Upper Cliff Bank, Stoke-on-Trent .. .. (1904-05)
AULANIER, ROBERT E., "Ceramique Française," Gargenville (S & O). .. .. (1921-22)
*AYNSLEY, J. G., c/o John Aynsley & Sons, Longton.. .. (1905-06)

BAGGALEY, J., Langford House, 47, Carlisle Street, Dresden, Stoke-on-Trent .. .. (1921-22)
BAILEY, A., 12, Mellard Street, Newcastle .. .. .. (1916-17)
*BAILEY, C., Bulkeley Hall, Woore, nr. Crewe.. .. .. (1914-15)
BAILEY, J. C., New Park, Trentham .. .. (1913-14)
BAILEY, P., Mere House, Rode Heath, Stoke-on-Trent .. (1907-08)
BAILEY, PETER & SONS, Ltd., Heaton Mersey Pottery and Brickworks, near Manchester.. .. .. (1918-19)
BAKER, G. F., The Madura Co., Ltd., Feroke Tile Works, Feroke, Malabar, India .. .. (1918-19)
BAKEWELL, W., Yeovil House, Regent Street, Stoke-on-Trent (1917-18)
BAKEWELL, W. M., Yeovil House, Regent Street, Stoke-on-Trent .. .. (1917-18)
BALAPPA, C. V., R. S. Ahobal & Co., Avenue Road, Bangalore (1922-23)
City, Mysore State, India .. .. (1918-19)
BALL, S. R. 14, Morley Street, Tunstall .. .. (1918-19)
BANKS, P. K., Empingham Hill, Stamford .. .. .. (1916-17)
BARKBY, H., 56, Honeywall, Stoke-on-Trent .. .. .. (1915-16)
BARRATT, M., 17, Gledhow Avenue, Leeds .. .. .. (1907-08)
BARRINGER, LAURENCE E., 108, Lenox Rd., Schenectady, N.Y., U.S.A. .. .. (1918-19)
BATES, T., Kirkham Street, Stoke-on-Trent .. .. .. (1906-07)
BAUGH, T., El. Wedy. Kafr Ammar, Upper Egypt .. .. (1918-19)
BAXENDALE, W. R., 87, Greenway Street, Darwen, Lancs... (1916-17)
BEDSON, W., Lawrence Rd., Trenton, N.J., U.S.A., R.F.D., No. 4 .. .. (1909-10)
BENN, JOSEPH E., Hill House, Wortley, Leeds .. .. (1921-22)
*BENSON, WM. & SON, Ltd., Collingwood Buildings, Newcastle-on-Tyne .. .. (1916-17)
BENTLEY, R., 109, High Lane, Burslem, Stoke-on-Trent .. (1922-23)
BHAGAT, G., The Palms, Lahore, India .. .. (1918-19)
BIGOT, Dr. A., 112, Avenue de Suffren, Paris, XV. .. .. (1918-19)
BILLINGTON, C., c/o Messrs. Billington & Newton, .. Longport .. .. (1918-19)
BINNS, C. F., Alfred University, New York, U.S.A... .. (1903-04)
BIRD & Co., The Kumardhubi Fireclay & Silica Works Co., Ltd., Chartered Bank Buildings, Calcutta .. .. .. (1918-19)
BISHOP & STONIER, Hanley, Staffs. .. .. (1905-06)
BISPHAM HALL COLLIERY Co., Orrell, near Wigan .. (1916-17)
BLACK, C., C/o Messrs. James Pearson, Ltd., Brampton, Chesterfield .. .. (1909-10)
BLACK, A. J. D., 159, Gorton Road, Reddish, Stockport.. (1920-21)
BLAIR, G., Normacot, Longton.. .. .. (1905-06)
BLOORE, R. B., Solby, Victoria Road, Tunstall .. .. (1913-14)
BLYTHE COLOUR WORKS, Cresswell, Stoke-on-Trent .. (1918-19)
BOAM, FRANK J., 35, Silver Street, Leicester.. .. .. (1917-18)
BOCH, FRERES, Messieurs, La Louviere, Belgium .. .. (1918-19)
BOLCKOW, VAUGHAN & Co., Ltd., Middlesbrough.. .. (1917-18)
BOLSOVER, G. R., 31, Rossington Road, Brocco Bank, Sheffield .. .. (1917-18)
BOULTON, F. D., Hawthorn House, Porthill, Stoke-on-Trent (1912-13)
BOWEN, G. M., c/o Bowen & Edwards, Northwood Street, Birmingham .. .. (1918-19)
BOURNE & LEIGH, Leighton Pottery, Burslem, Staffs. .. (1918-19)

BOWERS, C. H., The Beeches, Silverdale Road, Wolstanton.. (1911-12)
BOYCOTT, J. H., Thornbury, Fields Road, Alsager .. .. (1909-10)
BRADBURN R., Normanby Brick Works, Normanby, S.O. (1916-17)
BRADLEY, C. W., Woodleigh, Weston Coyney, Stoke-on-Trent (1921-22)
BRADSHAW, Dr. L., Chemist's Club, 52, East 41st Street, New York .. .. (1918-19)
BRANNAM, J. W., c/o C W. Brannan, Ltd., Litchdon Pottery, Barnstaple, Devon .. .. (1907-08)
BRAY, Messrs. G. & Co., Ltd., Leeds .. .. (1909-10)
BRAYSHAW, SHIPLEY N., 83, Carlton Road, Whalley Range, Manchester. .. .. (1917-18)
BREARLEY, HARRY, c/o Messrs. Brown, Bayleys Steel Works, Ltd., Sheffield .. .. (1916-17)
BRITISH CAST IRON Co. (The), Central House, New Street, Birmingham .. .. (1922-23)
BRITISH COMMERCIAL GAS ASSOCIATION, (Mrs. M. A. Cloudesley-Brereton, Editor, 7, Lyndhurst Road, Hampstead, N.W. 3. .. .. (1921-22)
BRITTAINS, Ltd., Cheddleton Paper Mills, Cheddleton, nr. Leek, Staffs. .. .. (1922-23)
BROOKE, G. B., F.I.C., M.I.M.M., The British Aluminium Co., Ltd., Kinlochleven, N.B. (London Office) 109, Queen Victoria Street, London, E.C. .. .. (1921-22)
BROOKE STANLEY, c/o Oughtibridge Silica Fire Brick Co., Ltd., Oughtibridge .. .. (1921-22)
BROOKES, Ltd., Halifax, Yorkshire .. .. (1916-17)
BROWN, COLIN, Mc. N.H., Barncluith, Paisley .. .. (1921-22)
BROWN, H. Goulding, 28, Titchborne Street, Hyde Park, W. 2 (1921-22)
BROWN, R., c/o Robert Brown & Son, Ltd., Ferguslie Works, Paisley .. .. (1910-11)
BROWN, R. S., Brimsdown, Middlesex.. .. .. .. (1914-15)
BROWN, HENRY S., 21, Oakshaw, Paisley .. .. .. (1916-17)
BRUCE, A. K., Gresham House, Old Broad Street, London, E.C. (1916-17)
BRUNNER, MOND & Co., Ltd., Northwich. .. .. .. (1921-22)
BRYMBO STEEL Co., Ltd., near Wrexham .. .. .. (1916-17)
BUCK, E. H., 1, Spencer Gardens, East Sheen, Surrey.. .. (1916-17)
*BUCKLEY BRICK & TILE Co., Ltd. (Gibsons), Buckley, via Chester .. .. (1908-9)
BULLERS, Ltd., Hanley, Stoke-on-Trent .. .. .. (1917-18)
BULLOCK, R. F., 256, Waterloo Road, Cobridge .. .. (1918-19)
BURNAND, GUY, Sneyd Colour Works, Princes Street, Burslem (1921-22)
*BURTON, J., The Pottery, Clifton Junction, Manchester .. (1905-06)
*BURTON, W., M.A., F.C.S., 39, Queensborough Terrace, Bayswater, London, W 2 .. .. (1900-01)

CALLCOTT, J. A., Hazeldene, Spratslade Drive, Longton .. (1905-06)
*CAMPBELL, A. J., c/o Minton's, Ltd., China Works, Stoke-on-Trent .. .. (1906-07)
CAMPBELL, WM., Heathfield House, 68, Pall Mall, Hanley.. (1917-18)
CAMPBELL & Co., Roughhearthe Ganister Works, Falkirk .. (1917-18)
CAMPBELL, GEORGE, The Campbell Tile Co., Stoke-on-Trent .. .. (1918-19)
CAPPER, B., Fordham, King's Avenue, Wolstanton .. .. (1921-22)
CARDER, C., & SONS, Brierley Hill, South Staffordshire. .. (1921-22)
CARNALL, F., 35, Keelings Drive, Stoke Lodge Estate, Stoke-on-Trent.. .. .. (1916-17)
CARNEGIE LIBRARY OF PITTSBURG, (T. Hewitt, Head of Order Dept.) Pittsburgh, Pa., U.S.A. .. .. .. (1918-19)
CARTER, R. C., Bell View, Poole, Dorset .. .. .. (1912-13)
CARTLIDGE, A., The Maitlands, Harpfield, Stoke-on-Trent.. (1904-05)
CARTWRIGHT, J. T., 3, Cadogan Street, Glasgow.. .. (1921-22)

CASTLECARY FIRECLAY Co., Castlecary, by Bonnybridge. (1917-18)
CASEY, Major, R. G., D.S.O., M.C., Mount Morgan Mining Co., Ltd., 125, William Street, Melbourne, Australia .. (1918-19)
CHAMBERS, CHARLES JOHN, Rua Candido dos Reis, 99, Porto, Portugal .. .. (1921-22)
CHAMPION, ALBERT, c/o Champion Ignition Co., Flint, Michigan, U.S.A. .. .. (1918-19)
CHANDORKAR, R. D., Paisa Fund Glass Works, Talegaon, (Dabhada) India .. .. (1918-19)
CHANDLER, L. L., Research Laboratory, Pittsburg Plate-glass Co., Creighton Pa, U.S.A. .. .. (1911-12)
CHARTRES, C. B., c/o Burn & Co., Ltd., 7, Hasting Street, Calcutta .. .. (1917-18)
CLARK, EDWARD S., Llay Cottage, Gresford, Wrexham .. (1917-18)
CLAY RING Co., Ltd., 55, Garratt Lane, Wandsworth, S.W. 18 (1920-21)
CLEGG, D. T., Middleton Grange, Hunslet Carr, Leeds .. .. (1922-23)
CLEVELAND Public Library, (The Librarian) Ohio, U.S.A. .. (1912-13)
CLEVERLEY, WM. B., Junr., 25, Alderley Road, Flixton, Manchester .. .. (1913-14)
CLELAND, G., Heathfield Fireclay Works, Chryston, near Glasgow .. .. (1918-19)
CLEWS, P. S., Victoria Road, Tunstall.. .. .. .. (1916-17)
CLIFF, A., Rock Lodge, Stamford .. .. (1913-14)
CLIVE, HAROLD, c/o Newhall Pottery Co., Hanley, Staffs. (1918-19)
*COBB, J. W., c/o The University, Leeds.. .. .. .. (1904-05)
CODLING, B. P., Karma, Victoria Road, Tunstall .. .. (1909-10)
COLCLOUGH, ERNEST, Enfield, Church Road, Alsager .. (1921-22)
COLCLOUGH, J. H., Marsh Avenue, Wolstanton .. .. (1905-06)
COLCLOUGH, H. T., Eric House, Stone Road, Longton .. (1916-17)
COLMAN, H. G., D.Sc., Ph.D., 1, Arundel Street, Strand, W.C. (1916-17)
COLVILLE, DAVID, & SONS, Ltd., 195, West George Street, Glasgow .. .. (1917-18)
CONSETT IRON Co., Ltd., Consett, Durham .. .. (1920-21)
CONSTRUCTION DE FOURS: CIE GE de 32 et 34, Rue de la Grange-aux-Belles, Paris. XC. .. .. (1918-19)
COOK, GEORGE N., Parkhead Steel Works, Glasgow.. .. (1917-18)
COOKE, A. W., 40, High Street, Wolstanton .. .. .. (1918-19)
COOPER, H. F., 38, Trent Terrace, Hanley .. .. .. (1921-22)
COOPER, P. S., Partington Steel & Iron Co., Irlam, Manchester .. .. (1918-19)
COPPEE, Co., Ltd., 44, Grosvenor Place, London, S.W., 1 .. (1918-19)
CORN, E. R., Henry Richards Tile Co., Tunstall .. .. (1908-09)
CORN, E. R. G., Tolima, Trentham .. .. (1918-19)
COTTON, A., Nelson Pottery, Hanley .. .. (1912-13)
COUPAR, A., Bassilow Farm, Fenton, Stoke-on-Trent .. (1914-15)
COX, PAUL E., Dept. of Ceramic Engineering, Iowa State College, Ames, Iowa, U.S.A. .. .. (1912-22)
CRAWFORD, GEO., 11, Strathattan Crescent, Douglas, I.O.M. (1916-17)
CRONQUIST, G. W., Hëlsingborg, Sweden .. .. .. (1922-23)
CRONSHAW, Dr. H. B., Technical Institute, Brierley Hill, South Staffs. .. .. (1920-21)
CROW, ROBERT, Cruffell, Marraville, Melbourne, Australia (1918-19)
CULLINAN, D., Olifants Fontein, Transvaal, S. Africa .. (1921-22)
CULLINAN, R. V., c/o Box 286, Johannesburg, S. Africa .. (1913-14)
CUMING, N. F., c/o Cuming, Smith & Co., Ltd., 65, William Street, Melbourne, Australia .. .. (1921-22)
CYPLES, W. H., Trentham Road, Longton .. .. .. (1906-07)

DALE, A. J., 14, Uttoxeter Road, Longton .. .. .. (1922-23)
DAVIDSON, J. H., M.Sc., Messrs. Wood Bros., Glass Co., Ltd., Pontefract Road, Barnsley. .. .. (1903-04)

DAVIE, C., Messrs. N. B. Allen & Co., Ltd., Hirwain, South Wales .. .. (1917-18)
DAVIS, TURNBULL & Co., 4 & 5, Prudential Buildings, Sheffield .. .. (1920-21)
DAVISON, J. A., Porthill, Stoke-on-Trent .. .. .. (1905-06)
DEB, S., 45, Tangra Road, Calcutta, India .. .. .. (1918-19)
DEELEY, J. H. A., 16, Baylie Street, Stourbridge .. (1912-13)
DENNIS, F. W., Holly Cottage, Ricardo Street, Dresden .. (1911-12)
DERBYSHIRE SILICA FIRE BRICK Co., Friden Station, Hartington, near Buxton .. .. (1921-21)
DETROIT PUBLIC LIBRARY, Detroit, Mich, U.S.A. .. (1922-23)
*DEVEREUX, P. S., c/o The British Abrasive Wheel Co., Ltd., Tinsley, Sheffield .. .. (1912-13)
DUNSMUIR, G., c/o Hillview, Bonnybridge, Stirlingshire .. (1916-17)
DODD, W. H., 147, Bucknall New Road, Hanley, Stoke-on-Trent (1909-10)
DOLBY, W. J., 24, Whitfield Avenue, Newcastle, Staffs. .. (1920-21)
DOUGALL, JAMES & SONS, Ltd., Firebrick Works, Bonnybridge, Stirlingshire .. .. (1916-17)
DOUGLAS FIREBRICK Co., Ltd., Kilwinning .. .. (1916-17)
DRESSLER TUNNEL OVENS, Ltd., Argyle Works, Carter's Crossing, Fenton .. .. (1916-17)
DRESSLER, PHILIP, 1551, East Boulevard, Cleveland, Ohio, U.S.A. .. .. (1918-19)
*DUFFIELD, F., L, The Derbyshire Basic Co., Ltd., 99 Pinstone Street, Sheffield .. .. (1921-22)
DUNN, F. T., Messrs. The Henry Richards Tile Co., Tunstall, Stoke-on-Trent .. .. (1906-07)
*DUNN, J. T., D.Sc., F.I.C., Public Analysts' Laboratory, 10, Dean Street, Newcastle-on-Tyne .. .. .. (1916-17)

EARDLEY, DONALD, 184, Lower Chaplin Road, Florence, Longton .. .. (1920-21)
EDINBURGH & LEITH FLINT GLASS WOKKS, Norton Park, Edinburgh .. .. (1916-17)
EDWARDS, A. O., c/o The Yorkshire Refractories Co., Ltd., 27, Waterdale, Doncaster .. .. (1917-18)
EDWARDS, J. C., Terra Cotta Works, Ruabon .. .. (1921-22)
EDWARDS, W. H., Park Lane, Fenton, Stoke-on-Trent .. (1921-22)
EGLINTON MAGNESITE BRICK Co., Ltd., Dundyvan Brick Works, Coatbridge .. .. (1917-18)
ELLAND FIRECLAY Co., Ltd., Calder Fireclay Works, Elland (1916-17)
ELLIS, THOS., Penwyllt, near Neath .. .. (1916-17)
ELEY, ERNEST E., 15, Lord Street, Basford, Stoke-on-Trent (1920-21)
*EMERY, W., 7, Catherine Street, May Bank, Staffs. .. .. (1902-03)
ENDELL, K. Dr., Berlin Steglitz, Breitestrasse 3, Germany.. (1920-21)
ETCHELLS, H., 56, Westwood Road, Sheffield.. .. .. (1917-18)
EVERITT, CHARLES KINGSTON, c/o Edgar Allen & Co., Ltd., Imperial Steel Works, Sheffield .. .. .. (1916-17)

FAILL, JAMES, 146, West Regent Street, Glasgow .. .. (1916-17)
FARNLEY IRON Co., Ltd., Farnley, near Leeds .. .. (1916-17)
FEARNSIDES, W. G., 11, Ranmoor Crescent, Sheffield .. (1916-17)
FERN, E. R., School of Art, Bombay .. .. (1906-07)
*FIELDING, A., Devon Pottery, Stoke-on-Trent .. .. (1902-03)
FIELDING, R., Devon Pottery, Stoke-on-Trent .. .. (1906-07)
FINN, R., 2, Eaton Street, Hanley .. .. (1920-21)
FOLEY, F. D., Loch Lomond Road, St. John's, N.B., Canada (1917-18)
FORD, SAMUEL & Co., Lincoln Pottery, Burslem .. .. (1921-22)
FOSTER, HENRY & Co. Ltd., Backworth, Newcastle-on-Tyne (1916-17)
*FOSTER, J. E., 48, Gilman Street, Hanley .. .. .. (1909-10)
*FOX, W. G., 44, Riseley Road, Hartshill, Stoke-on-Trent .. (1912-13)
FOXWELL, G. E., 70, Steade Road, Sharrow, Sheffield .. (1916-17)

FREEMAN, Dr. LUDFORD, Abbotsthorpe, Carnarvon Road, Redland, Bristol .. .. (1914-15)
FULPER, W. H., c/o The Fulper Pottery Co., Flemington, N.J., U.S.A. .. .. (1910-11)

GARDNER, W. J., c/o The Meltham Silica Brick Co., Ltd., Meltham, near Huddersfield.. .. .. (1916-17)
GARDNER, W. T., F.C.S., 14, Beechwood Avenue, Kew Gardens, London, S.W. .. .. (1918-19)
GATENSBURY, H. R., Atlas Foundry, Victoria Road, Hanley (1913-14)
GIBBONS, Ltd., Dibdale Works, Dudley .. .. .. (1916-17)
GIBSON, H. M., c/o The A. Y. Dinas Silica Brick Co., Ltd., 37, Lady Street, Kidwelly, S. Wales .. .. .. (1916-17)
GIBBS, A. E., 1006, Widner Buildings, Philadelphia, Pa., U.S.A. .. .. (1918-19)
GIBSON, W. F. 125, Tweedale Street, Rochdale.. .. .. (1909-10)
GILL, W. R., Cleveland Villa, Castleford, Yorkshire.. .. (1909-10)
GILL, G. M., 13, Queens Park, Caterham, Surrey.. .. .. (1922-23)
GIMSON, J. F., 69, Fountain Square, Fenton, Stoke-on-Trent (1920-21)
GIPP, H. W., c/o Electrolytic Zinc Co. of Australia, Risdon Road, Hobert, Tasmania .. .. (1918-19)
GLASS RESEARCH ASSOCIATION, The, 50, Bedford Square, London, W.C. 1. .. .. (1920-21)
GLENBOIG UNION FIRECLAY Co., Ltd., Glenboig, Scotland (1916-17)
GLEAVES, E., Alsager House, Marsh Avenue, Wolstanton, Stoke-on-Trent .. .. (1920-21)
GLOVER, SAMUEL, F.R.M.S., Olive Mount, St. Anns, St. Helens .. .. (1916-17)
GODDARD, J. V., Trentham .. .. (1905-06)
GODDARD, A. H., c/o Messrs. G. L. Ashworth Bros., Ltd., Hanley .. .. (1918-19)
GOODWIN, F. T. H., Hollydean, Park Avenue, Longton .. (1910-11)
GODWIN, A. F., c/o J. Bourne & Son, Denby Pottery, Derby.. (1915-16)
GOODWIN, W. E., Watcombe House, 225, Waterloo Road, Burslem .. .. (1902-03)
GOODWIN, JOHN, Foley Works, Fenton, Stoke-on-Trent .. (1920-21)
GOSLING, JAS., Atlas Foundry, Victoria Road, Hanley .. (1913-14)
GOSS, W. H., Falcon Pottery, Stoke .. .. (1914-15)
GRAHAM, J. W., Ashley Villa, Lancaster Av., Newcastle Staffs. .. .. (1914-15)
GRAY, A. E., Glebe Works, Mayer Street, Hanley .. .. (1917-18)
GRAYSON, LOWOOD, J. & Co., Ltd., Deepcar, near Sheffield (1916-17)
GRAY, J., Auldhaven, Milngavie .. .. (1918-19)
GREAVES-WALKER, A. F., Box 1122, Pittsburgh, Pa, U.S.A. .. .. (1920-21)
GREEN, A. T., 579, High Lane, Burslem, Stoke-on-Trent .. (1917-18)
GREEN, G. D., Hobbergate, Brampton, Newcastle .. .. (1921-22)
GREEN, J. C., 49, Bromley Road, Kingswinsford, Staffs. .. (1911-12)
*GREEN, S. A., Brampton Hill, Newcastle, Staffs. .. .. (1905-06)
GREGORY, C., Newfield, Willington, Co. Durham .. .. (1916-17)
GREGORY, J. G. & SON, Friars Street, Newcastle, Staffs .. (1921-22)
GREGORY, REDDISH & Co., Ltd., Silica & Firebrick Works, Deepcar, near Sheffield .. .. (1916-17)
GRICE, E., 21, Station Road, Meir, Longton, Staffs. .. .. (1913-14)
GRIMWADE, C. D., Fairlands, Trent Vale, Stoke-on-Trent .. (1918-19)
GRINDLEY, W. H., Woodland Pottery, Tunstall .. .. (1906-07)
GRIFFITHS, F. G., Quarter Denny, Stirlingshire .. .. (1918-19)
GROCOTT, W., 75, Shenstone Road, Edgbaston, Birmingham (1918-19)

HAGUE, A. P., The Rookery, Dranfield, near Sheffield .. (1920-21)
HALL, HY., The Bungalow, Botteslow, Hanley.. .. .. (1912-13)
HALL, J. & Co., Stourbridge .. .. (1916-17)

HAMILTON, J., Ideal Pottery, Trenton Potteries Co., Trenton, U.S.A. .. .. (1906-07)
HAMILTON, WILLIAM, 93, West George Street, Glasgow .. (1917-18)
HAMMOND, PERCY, Newbridge House, Bollington, Macclesfield .. .. (1916-17)
HAMMOND, WILLIAM, Jevington, Bollington, Macclesfield (1916-17)
HAMPTON, T. E., Eastwood Marl Works, Hanley .. .. (1908-09)
HANCOCK, E. A., Kepax, Worcester .. .. (1916-17)
HANCOCK, F., Ford Street, Shelton, Stoke-on-Trent.. .. (1902-03)
HANCOCK, W. C., B.A., F.I.C., 60, Greek Street, Soho Square, London, W.1 .. .. (1917-18)
HARBORD, F. W., 16, Victoria Street, London, S.W. .. (1916-17)
HARDING, F. W., 6, Hassell Street, Hanley .. .. .. (1921-22)
HARRIS, GUY, Messrs. Bullers, Ltd., Milton .. .. .. (1922-23)
HARRISON, A. C. Bath Street, Hanley .. .. .. (1910-11)
HARRIMAN, WM., & Co., Ltd., 51, Westgate Road, Newcastle-on-Tyne .. .. (1917-18)
HARRINGTON, T. H., The Square, Ironbridge, Salop .. (1913-14)
HARRISON, T. S., May Place, Newcastle, Staffs. .. .. (1921-22)
HARTLEY, H. L., Castleford Pottery, Castleford, Yorks .. (1917-18)
HARTMANN, M. L., The Carborundum Co. Niagara Falls, N.Y., U.S.A. .. .. (1921-22)
HARVEY, G., 78, Baskerville Road, Hanley .. .. .. (1921-22)
HASSALL, W., Tresco House, Woodville, Burton-on-Trent (1920-21)
HAUNCHWOOD BRICK & TILE Co., Ltd., Nuneaton .. (1921-22)
HAWTHORN, S., Mona House, Congleton, Cheshire.. .. (1905-06)
HAWLEY, E., Woodland Cottage, Blurton, Staffs. .. .. (1914-15)
HAWLEY, ERNEST, c/o Messrs. Hawley & Jackson, Longton (1913-14)
HAWLEY, W. S., Fairmont, Sunny Bank Road, Newcastle, Staffs. .. .. (1908-09)
*HEATH, A., 61, Bethesda Street, Hanley .. .. .. (1900-01)
HEATH, B. C., St. Edmunds Avenue, Porthill, Staffs. .. .. (1921-22)
HEATH, C. H., High Street, Woodville, near Burton-on-Trent (1915-16)
HEATON, J., Ravenhead, St. Helens .. .. (1916-17)
HEATON, WM., Ravenhead Brick Co., Upholland, near Wigan (1917-18)
HENDERSON, H. B., 1538, N. High St., Columbus, Ohio, U.S.A. .. .. (1911-12)
HENDERSON, J. D., c/o The Anglo-Greek Magnesite Co., 24, Finsbury Square, London, E.C. .. .. (1917-18)
HEPWORTH IRON Co., Ltd., Hazlehead, near Sheffield .. (1916-17)
HEYS, F. W., Hydro., Kilmacolm, Scotland .. .. .. (1921-22)
HEWITT, A. E., Easedale, Trentham, Stoke-on-Trent .. (1912-13)
HEWITT, F. G., 6, Boughey Street, Stoke-on-Trent .. .. (1918-19)
HICKMAN, & Co., Fireclay Works, Stourbridge .. .. (1916-17)
HIGGINS, F. W., Carborundum Co., Ltd., Trafford Park, Manchester .. .. (1918-19)
HILL, F. W., c/o Reliance Firebrick Pottery Co., Chanch, P.O. Baraker, E.I.R., Bengal, India .. .. .. (1917-18)
HILL, WESTLAKE & Co., Ltd., 8 Gloucester Sq., Southampton (1920-21)
HIMLEY FIRE & RED BRICK Co., Ltd., near Dudley .. (1916-17)
HINCHLIFFE, HERBERT, Bullhouse Colliery, Penistone, Sheffield .. .. (1917-18)
HIND, S. R., 48, Colclough Road, Meir, Stoke-on-Trent .. (1918-19)
HOBBS, W. E., Dyserth, Flintshire .. .. (1916-17)
HODSON, G. A., c/o The Hathern Station Brick & Terra-Cotta Co., Ltd., Loughborough .. .. (1908-09)
*HOLDCROFT, A. D., Bradwell Lane, Wolstanton .. .. (1902-03)
*HOLDCROFT, J. P., Bradwell Lane, Wolstanton .. .. (1902-03)
HOLLINSHEAD, T., The Elms Penkhull, Stoke-on-Trent .. (1906-07)
HOPE, H., Liverton, nr. Newton Abbot, Devon.. .. .. (1907-09)
HOPE, G. W., The Dingle Fingringhoe, Colchester .. .. (1920-21)

HOULDSWORTH, H. S., 10, Rydal Terrace, Heckmondwicke, Yorks .. .. (1921-22)
HOWELL, C. G., 90, Leonard Road, Birches Head, Hanley .. (1916-17)
HOWELL, W. E., 41, Sneyd Terrace, Burslem .. .. .. (1915-16)
HOWLETT, S. & J., 23, Broom Street, Hanley .. .. (1918-19)
HOWIE, F. C., Hurlford Fireclay Works, Kilmarnock .. (1916-17)
HOWSON, R. G., c/o Messrs. G. Howson & Sons, Limited, Hanley .. .. (1907-08)
HUBBARD, A. E., c/o Messrs. George Tumbull & Co., Dykehead Works, Bonnybridge, Stirlingshire .. .. (1922-23)
HUGHES, F. S., Opal China Works, Fenton, Staffs. .. .. (1909-10)
HUNT, PERCY, Whiteley Cottage, Marehay, Derbyshire .. (1921-22)
HURLL, Ltd., P. & M., 144, West Regent Street, Glasgow .. (1917-18)
HUTTON, R. S., D.Sc., Castle Hill, High Wycombe, Bucks .. (1916-17)

IVERS, B., Marikuppam, Kola Gold Fields, South India .. (1922-23)

JACKSON, G. J., Thanet House, Strand, W.C.2 .. .. (1917-18)
JACKSON, CHARLES E., Warwick China Co., Wheeling, Pa., U.S.A. .. .. (1922-23)
JACKSON, E. W., F.I.C., Godrevy, Saltburn-by-the-Sea .. (1918-19)
JACOBSEN, CARL, Malmegade 7, Copenhagen, Denmark
JAMES, W., Grimwades, Ltd., Winton Pottery, Stoke-on-Trent (1921-22)
JEFFREY, Dr. J. A., c/o Champion Porcelain Co., Detroit, Mich., U.S.A. .. .. (1917-18
JEPPSON, G. N., 41, Burncoat Street, Worcester, Mass., U.S.A. .. .. (1912-13)
JOHNSON, A. S., c/o Messrs. Alfred Meakin, Ltd., Tunstall.. (1909-10)
JOHNSON, S. Ltd., Brittania Pottery, Burslem, Stoke-on-Trent .. .. (1920-21)
JOHNSTON, T. B., Park House, Eastfield Park, Weston-Super-Mare .. .. (1918-19)
JOHNSON, E., c/o Messrs. W. Boulton, Ltd., Navigation Rd., Burslem .. .. (1909-10)
JOHNSON, H., Tile Manufacturer, Highgate Tile Works, Tunstall .. .. (1906-07)
JOHNSON, J., Talke and Alsager Road, Alsager .. .. (1912-13)
JOHNSON, R. L., Oulton Rocks, Stone, Staffs... .. .. (1912-13)
JOHNSON, W. P., B.Sc., Foundry Lane, Wallheath, near Dudley .. .. (1910-11)
JOHNS, C., 404, Pitsmoor Road, Sheffield .. .. .. (1917-18)
JONES, A. B., Junr., Grafton Works, Longton .. .. .. (1914-15)
JONES, A. G., Lynton, Trentham, Staffs. .. .. .. (1909-10)
JONES, A. G. H., Heath House, Uttoxeter .. .. .. (1905-06)
JONES, CHARLES, Heatherfield, Bwlchgwyn, near Wrexham (1916-17)
JONES, CHESTER H., 1570, Old Colony Buildings, Chicago, U.S.A. .. .. (1921-22)
JONES, E. A., Glendene, Stallington Road, Blythe Bridge .. (1903-04)
JONES, GEO., & SONS, Ltd., Crescent Pottery, Stoke-on-Trent (1921-22)
JONES, L., Southwood, c/o Messrs. Southwood, Jones & Co., Danycraig Works, Risca, Monmouth .. .. .. (1916-17)
JONES, N. L., c/o J. & G. Meakin, Ltd., Hanley .. .. (1914-15)
*JONES, R. H. H., Riversdale, Keyberry Road, Newton Abbot (1900-01)
JONES, Sir W. J. 17, Victoria Street, Westminster, S.W.,1 .. (1916-17)
JONES, W. R., 3, Lenches Bridge, Pensnett, near Dudley .. (1921-22)
JONES, W. R. D., University College, Cardiff .. .. .. (1921-22)
JONES, AUSTIN, c/o Messrs. Edwards & Jones, Engineers, Longton, Stoke-on-Trent .. .. (1922-23)

KANHÄUSER, Dr. FRANZ, ředitel šamotových závodů Dr. Tonder & Co., Chodoz u Karl. Varu. Czechoslovakia .. (1922-23)

KEELING, F. A., c/o Messrs. Keeling & Walker, Stoke-on-Trent .. .. (1906-07)
KEELING, J., c/o Keeling & Co., Dalehall, Burslem .. .. (1906-07)
KEELING, G. A., Brown Edge Road, Stockton Brook, Stoke-on-Trent .. .. (1918-19)
KENT, W. F., 72, Leonard Street, Burslem .. .. .. (1903-04)
KENT, W., c/o. Messrs. Taylor Tunnicliff & Co., Hanley, Stoke-on-Trent .. .. (1920-21)
KILNER, N. S., Hepworth Chambers, Briggate, Leeds.. .. (1918-19)
KIRKLAND, H. S., Albion Pottery, Etruria, Stoke-on-Trent (1906-07)
KLEIN, CARL, A., 4, Brimsdown Av., Enfield Highway, Middlesex .. .. (1915-16)
KNIGHT, W. C., Westholme, Barnfields, Penkhull, Stoke-on-Trent.. .. .. (1908-09)
KREHBIEL, J. F., 168E, Lake view Avenue, Columbus, Ohio, U.S.A. .. .. (1917-18)

LADREDA, F. F., Capitan de Arbillena San Clandio (Oviedo), Spain .. .. (1922-23)
LANCASTER, E., Lyndhurst, Trentham .. .. .. (1914-15)
LAPORTE, B., Ltd., Soap and Chemical Works, Luton, Beds... (1922-23)
LEACH, C. A., Padeswood, Weston Coyney, Stoke-on-Trent.. (1922-23)
LEATHER, J. P., Gas Works, Burnley .. .. (1916-17)
LEEDS FIRECLAY Co., Ltd., Wortley, Leeds.. .. .. (1916-17)
*LEESE, A., 81, Vivian Road, Fenton, Staffs. .. .. .. (1900-01)
LEIGH, A. K., Cranbourne, Oulton Cross, Stone, Staffs. .. (1914-15)
LESSING, R., PhD., The Laboratory, Southampton House, 317 High Holborn, London .. .. (1910-11)
LEWIS, E. H., The Green, Wishaw, Scotland .. .. .. (1917-18)
LILLESHALL (The) Co., Ltd., Priors Le: Hall, Shifnal, Salop (1916-17)
LILLIBRIDGE, H. D., c/o American Encaustic Tiling C:.. Ltd. Zanesville, Ohio, U.S.A. .. .. (1916-17)
LINDOP, R. C., 41, Grove Road, Fenton.. .. .. .. (1913-14)
LINSTRUM, T., Peacocks Bdg., 23, Park Row, Leeds.. .. (1917-18)
LLOYD, HORACE, Messrs. N. B. Allen & Co., Ltd., Hirwain, South Wales .. .. (1917-18)
LLOYD, W. J., Rothesay, King's Avenue, Wolstanton .. (1915-16)
LLOYD, T. H., c/o The Pure Bone Phosphate Co., 27, Kirkgate, Newark .. .. (1918-19)
LOCKHART, D. B., Victoria Pottery, Pollokshaws, Glasgow (1918-19)
LOMAS, ALEX, Messrs. J. & J. Dyson, Ltd., Griffs Fireclay Works, Stannington, nr. Sheffield .. .. (1922-23)
LOMAX, J. R., 327, Bury Road, Bolton.. .. .. .. (1917-18)
LOUDON, JOHN, Loudon & Russell, Ltd., Allanton Fireclay Works, Newmains, Scotland.. .. .. .. (1917-18)
LOVATT, L. D., 79, Festing Street, Hanley .. .. .. (1916-17)
LOXTON, N. G., Leeds Fireclay Co., Burmantofts Works. Leeds (1918-19)
LUCAS, W. T., The Limes, Alsager .. .. (1921-22)
LYSAGHT, J., Ltd., Normanby Park Works, Scunthorpe, Lincs. (1918-19)

MACHIN, C. W., 65, Trentham Road, Longton .. .. (1914-15)
Mc KINLAY, PARKER, "Benhar," Otago, New Zealand .. (1921-22)
MacNEAL, C., Lloyds Bank Chambers, Fenton, Staffs. .. .. (1910-11)
MacWHIRTER, J., Elsinore, Milngavie, Scotland .. .. (1917-18)
McCORMICK, J., Dock Office, Hull, Yorks. .. .. .. (1917-18)
McCANCE, Dr. A., Westview, Uddingston .. .. .. (1918-19)
McDOWELL, J. S., 1800, Farmers Bank Buildings, Pittsburgh, U.S.A. .. .. (1918-19)
McNEIL, GEORGE, 181, Main Street, Bellshill, Lanarkshire .. (1918-19)
MALINOVSZKY, A., 22, N. Douglas Avenue, Belleville, Ill., U.S.A. .. .. (1916-17)
MALKIN, S., c/o The Malkin Tile Works Co., Burslem .. (1905-06)

MALKIN, W. F., Dalehall Mill, Burslem .. .. .. (1914-15)
MALKIN, J. R., Penryn, Grosvenor Place, Wolstanton .. (1918-19)
MANSFIELD, F., 9, Red Cross Street, Liverpool .. .. (1918-19)
MARLOW, J. H., 19, The Villas, Stoke-on-Trent .. .. (1916-17)
MARSHALL, F. J., 48, Mayer Street, Hanley .. .. .. (1911-12)
MARTIN, GEOFFREY, Rosherville Court, Burch Road, Gravesend .. .. (1921-22)
MASON, ADAM & SONS, Ltd., Horwich, Lancashire.. .. (1916-17)
MASSACHUSETTS INSTITUTION OF TECHNOLOGY, Massachusetts Avenue, Cambridge Mass., U.S.A. .. .. (1922-23)
*MAYER, E. W. T., 11, Westwood Road, Wolstanton.. .. (1914-15)
MAW, J. S., 13, St John's Hill, Shrewsbury .. .. .. (1921-22)
MEADE, ALWYNE, Commercial Gas Co., Wapping, London, E. 1 .. .. (1916-17)
MEAKIN, J. & G., Ltd., Eagle Pottery, Hanley, Stoke-on-Trent (1918-19)
MEIR, J., The Barn, Grosvenor Place, Wolstanton .. .. (1911-12)
*MELLOR, J. W., D.Sc., Sandon House, Regent St., Stoke-on-Trent .. .. (1904-05)
MEREDITH, J., 42, Stanley Street, Tunstall .. .. .. (1911-12)
METHVEN DAVID & SONS, Kirkcaldy Pottery, Kirkcaldy .. (1922-23)
MICHELSEN, H. C., 20, Essex Street, Strand, London, W.C., 2 (1921-22)
MICHIE, A. C., 12, Akenside Hill, Newcastle-on-Tyne .. (1910-11)
MIDDLETON FIRECLAY WORKS, Leeds .. .. .. (1916-17)
MILLS, F. E., Brentford Gas Co., Brentford, Middlesex .. (1921-22)
MITCHELL, JOHN, c/o A. Y. Dinas Silica Brick Co., Ltd., 142, Queen Street, Glasgow .. .. (1916-17)
MITCHELL, J. S., Hyland, Hargate Drive, Hale, Manchester (1917-18)
MOKIJI, ICBIJE, c/o. Kurasaki Togio Co., Kurasaki machi, Fukuokaken, Japan. .. .. (1922-23)
MOLLER, C. A., Vestergade, 33, Copenhagen, Denmark .. (1921-22)
MONIOKI, S., c/o Toyo Toki, Kwaisha, Shinozaki, nr. Kokura City, Japan .. .. (1916-17)
MONTGOMERY, ROBERT J., c/o Bausch & Lomb Optical Co., Co., Rochester, N.Y., U.S.A .. .. (1918-19)
MONTGOMERY, ALLAN W., 58, York Street, Glasgow .. (1918-19)
*MOORE, B., Draycott, Blythe Bridge, Stoke-on-Trent .. (1900-01)
MOORE, BERNARD, J., The Gables, Bromley Hough, Penkhull, Stoke-on-Trent .. .. (1913-14)
MOORE, C. H., 244, Fulwood Road, Sheffield .. .. (1917-18)
MOORE, CHRISTOPHER E,, The Hurst, Hagley, Stourbridge (1921-22)
MOORSHEAD, T.C., 40-43, Norfolk St., Strand, London, W.C.2. (1921-22)
MORETON WILLIAM P , c/o Messrs. Thos. Forrester & Sons, Ltd., Phœnix Works, Longton, Stoke-on-Trent .. .. (1921-22)
MORTON, JOSEPH, Ltd., Cinder Hill Fireclay Works, Halifax, Yorks. .. .. (1917-18)
MORRALL, F 49, Kensington Road, Oakhill, Stoke-on-Trent (1917-18)
MOSS. G. H., 47, Heron Street, Fenton, Stoke-on-Trent .. (1920-21)
MOTTRAM, GEO. WM., 1, Montague Street, London, W.C. 1 .. (1916-17)
MOULTON, D.A., Iowa State College, Dept. of Ceramic Engineering, Ames; Iowa U.S.A. .. .. (1918-19)
MOURITZEN, C. F., Calyx Paint Works, Lord Street, Perth, Western Australia .. .. (1920-21)
MYERS, E. M., The Indian Iron & Steel Co., Ltd., Hirapur, Works, Asansol, E.I.R., Bengal, India .. .. .. (1921-22)
MYOTT, A., c/o Messrs. Myott, Son & Co., Cobridge, Burslem (1904-05)

NEGUS, W., 36, Bloomsbury Square, London, W.C. 1 .. (1918-19)
NEWBY, F. B., c/o Malkin Tile Works, Burslem, Staffs .. (1917-18)
NEWMAN, H. S., Sunnyside, Oxford Road, Basford Park, Stoke-on-Trent .. .. (1917-18)
NEWSOM, F. S., c/o Pountney & Co., Ltd., Fishponds, Bristol.. (1922-23)

NEW YORK PUBLIC LIBRARY, 476, Fifth Avenue, New York, U.S.A. .. .. (1921-22)
NICHOLSON, E. D., Park Issa, Oswestry .. .. .. (1918-19)
NIXON, WM., Mayfield, Weston Coyney, Stoke-on-Trent .. (1916-17)
NOBLE, E., Birch House, Worksop .. .. (1917-18)

OATES & GREEN, Ltd., Halifax, Yorks. .. .. .. (1916-17)
OAKES, W. c/o. Sand, Glass & Foundry Materials (Amalgamated) Ltd., 27, Waterdale, Doncaster .. .. .. (1920-21)
*ODELBERG, A.S.W., Gustafsberg Pottery, Gustafsberg, Sweden (1904-05)
OKURA, K., 22, Ipponmattsu, Azab, Tokyo, Japan .. .. (1915-16)
*OLSEN, B., The Villas, Stockton Brook, Stoke-on-Trent .. (1900-01)
ORMANDY, W. R., D.Sc., 18, Belsize Grove, Belsize Park, N.W. 3. .. .. (1917-18)
ORTON, E., Columbus, Ohio, U.S.A. .. .. (1903-04)
OUGHTIBRIDGE SILICA FIREBRICK WORKS, The Oughtibridge, Sheffield .. .. (1916-17)
OWEN, T. WILFRED, 4, Dukes Place, St. Georges, Shropshire .. .. (1920-21)

*PAGE, E. P., 123, Abbey Foregate, Shrewsbury .. .. (1904-05)
PAINE, W. H. C., Calder Fireclay Co., Coatbridge .. .. (1916-17)
PAINE, J. W. R., Calder Fireclay Co., Coatbridge .. .. (1918-19)
PARKER, W. B., F.I.C., 1, Murrey Road, Rugby .. .. (1918-19)
PARKINSON & SPENCER, Ambler Thorn Fireclay Works, Halifax .. .. (1916-17)
PARMELEE, C. W., Professor of Ceramic Engineering, University of Illinois, Urbana, Illinois, U.S.A. .. .. (1906-07)
PASS, R. H., West Rising, Onondaga Pottery Co., Syracuse, N.Y., U.S.A. .. .. (1920-21)
PEARSALL, W. H., c/o Mobberley & Bayley, Stourbridge .. (1916-17)
PEARSON, E. J. & J., Ltd., Fireclay Works, Stourbridge .. (1916-17)
PEARSON & Co., The Potteries, Whittington Moor near Chesterfield .... (1918-19)
PEREGRINE, C. R., 5555, Forbes Street, Pittsburgh, Pennsylvania .. .. (1917-18)
PERRY, G. H. PEARSON, Portland House, Pedmore, nr. Stourbridge .. .. (1916-17)
*PERRY, T., 247, Campbell Road, Stoke-on-Trent .. .. (1910-11)
PICKFORD, HOLLAND & Co., Ltd., Eclipse Ganister Works, Attercliffe, Sheffield .. .. (1916-17)
PICKFORD, R. J., Thornlea, Carmel Road, Darlington .. (1917-18)
PIKE, L. G., Wareham, Dorset .. .. (1912-13)
PIMBLE, A. V., West Street, Penkhull, Stoke-on-Trent .. (1918-19)
PINHEIRO DA SILVA, ISRAEL CARTHE, Minas Gerais, Brazil, South America .. .. (1920-21)
PITCAIRN, G., Fabrica-de-Loza, San Juan de Aznal-farache, Sevilla, Spain .. .. (1916-17)
PLANT, F., Stone Road, Longton .. .. (1912-13)
*PLANT, H. J., Rostherne, Park Avenue, Longton, Stoke-on-Trent .. .. (1902-03)
PLANT, J., Melbourne House, Stone .. .. (1912-13)
PODMORE, A. J., Consall Hall, Consall, Stoke-on-Trent .. (1916-17)
PODMORE, WM., Consall Hall, Consall, Stoke-on-Trent .. (1913-14)
POLGREAN, J. H., 183, Leek New Road, Burslem .. .. (1921-22)
POOLE, THOS., Cobden Works, Longton .. .. .. (1915-16)
POOLE, HORACE, 96, Chaplin Road, Longton .. .. (1916-17)
POTTERY MANAGERS ASSOCIATION, A. E. Holdcroft, Sec., Woodland Avenue, High Lane, Burslem .. .. .. (1922-23)
POUNTNEY & Co., Ltd., The Bristol Pottery, Fishponds, near Bristol .. .. (1918-19)

POWELL, W. H., 41, Plymouth Street, Monteclair, New Jersey, U.S.A. .. .. (1908-09)
PRESTON, D., 35, High Street, Bucknall, Stoke-on-Trent .. (1916-17)
PRICE, G., Clifton, Silverdale Road, Wolstanton, Staffs. .. (1908-09)
PRICE, J. T. & Co., Ltd., Stourbridge .. .. (1916-17)
PRICE, S. H., "Lag-na-ha," Porthill, Stoke-on-Trent .. .. (1912-13)
PRYOR, E. A. COAD, The National Physical Laboratory, Teddington, Middlesex .. .. (1917-18)

*RAMSDEN, C. E., Foley Colour Works, Fenton, Stoke-on-Trent (1902-03)
RAMSAY, A., Mount Savage, Md., U.S.A. .. .. .. (1908-09)
RANN, R. C., 17, Victoria Street, Westminister, London, S.W. 1. .. .. (1918-19)
REDFERN & DRAKEFORD, Balmoral Works, Normacot, Stoke-on-Trent .. .. (1918-19)
REED, G. H., 1, Wear Street, Newfield, Willington, Co. Durham (1921-22)
REES, WALTER, J., Department of Refractory Materials, The University, Sheffield .. .. (1916-17)
RHEAD, F. H., Director, Research Dept., American Encaustic Tiling Co., Zanesville, Ohio, U.S.A. .. .. (1920-21)
RHEAD, T. F. E., 10, Malvern Road, Acocks Green, Birm'ham (1921-22)
REYNOLDS, G., Tachbroke House, Normacot.. .. .. (1903-04)
*RICHARDSON, A. G., "Linden," Oakville Avenue, High Lane, Burslem .. .. (1900-01)
RICHARDSON, GEO., 140, Pinnox Street, Tunstall
RICHARDSON, W. D., The Ceramic Engineering Co., 1466, Michigan Avenue, Columbus, Ohio, U.S.A... .. .. (1906-07)
RIDGE, H. M., 2, Great Winchester Street, E.C. 2 .. .. (1917-18)
RIDGWAY, B. Bedford Works, Hanley .. .. (1913-14)
RIDGWAY, F. J., H. Aynsley & Co., Commerce Street, Longton, Stoke-on-Trent .. .. (1921-22)
RIES, H., Cornell University, Ithaca, New York .. .. (1911-12)
RIGBY, A., 164, Trentham Road, Penkhull, Stoke-on-Trent (1920 21)
RIGBY, J. H., Buccleuch Road, Longton .. .. .. (1921-22)
RILEY, HAROLD E., Tresco, St., Austell .. .. .. (1917-18)
ROBERTS, J. G., c/o Messrs. Shanks & Co., Barrhead, N.B (1904-05)
ROBERTS & MAGINNIS, Ltd., Trevor, Ruabon, N. Wales .. (1921-22)
ROBERTSON, F. L., (Capt.) M.C.; B.Sc., 17, Riddrie Knowes, Glasgow .. .. (1921-22)
ROBINSON, H. M., c/o Messrs. Minton & Co., Ltd., Stoke-on-Trent .. .. (1909-10)
ROBINSON, H. T., China Works, Shelton, Stoke-on-Trent .. (1917-18)
ROBINSON, R. B., 20, Aynsley Terrace, Consett, Co. Durham.. (1922-23)
ROBERTSON, N. L., Dregham, Tanfield Road, Blowers Green, Dudley .. .. (1922-23)
RODGER, WYLIE, 18, Charles Street, St. Rollox, Glasgow (1918-19)
ROSS, DONALD W., The Findlay Clay Pot Co., Washington, Pa, U.S.A. .. .. (1917-18)
ROYCE, Miss F. A., 24, McKillop Street, Geelong, Victoria .. (1922-23)
ROWLEY, T. H., 63, Gilman Street, Hanley .. .. .. (1921-22)
*RUSSELL, FRANK, Highland Grove, Worksop .. .. (1916-17)
RUIZ, F., c/o Banco de Chile, 94, Gracechurch Street, London (1918-19)

SADLER, EDWARD, Newlands, Watlands Avenue, Wolstanton (1917-18)
SAILLY, PAUL, Compagnie Générale d'Electro-Céramique, 64, Rue Franklin, Ivry-Port, Seine, France .. .. (1917-18)
SALT, F., Central School of Science, Stoke-on-Trent .. .. (1922-23)
SANITER, E. H., Phoenix Special Steel Works, The Ickles, Sheffield .. .. (1916-17)
SANKEY, C. H., Wildcroft, Chislehurst, Kent.. .. .. (1916-17)
SATCH SHINZO, TOKIO ELECTRIC Co., Ltd., Kawaski, Kanagawa-Ken, Japan .. .. (1920-21)

SAXTON, C., 35, Bedford Street, Strand, London, W.C., 2 .. (1918-19)
SAYER, JAMES, Junr., Hill Crest, James St., Stoke-on-Trent (1912-13)
SCHURECHT, H. G., The Mellon Institute, University of Pittsburgh, Pittsburgh, Pa., U.S.A. .. .. (1922-23)
SCRIVENER, E. D., c/o Messrs. Taylor, Tunnicliff & Co., Eastwood, Hanley .. .. (1908-09)
*SCOTT, A., M.A., D.Sc., Central School of Science and Technology, Stoke-on-Trent .. .. (1917-18)
*SEARLE, A. B., The White Building, Sheffield.. .. .. (1907-08)
*SHAH, C. P., Sorab Dahal Tile Works, Than Road, Bombay.. (1913-14)
SHANKS, D., Raisdale, Barrhead, N.B. .. .. .. (1905-06)
SHAW, A. G., Whitebrick Brick Works, Darwen, Lancs. .. (1918-19)
SHAW, RITCHIE, Fylands Fireclay Works, Bishop Auckland, Co. Durham .. .. (1922-23)
SHENTON, R., c/o Messrs. Wedgwood & Co., Tunstall .. (1903-04)
SHEPPARD, P. N. F., 2, The Avenue, Beckenham, Kent .. (1917-18)
SHERLOCK, A., Winterton Pottery, High Street, Longton .. (1916-17)
SHIRLEY, T. H. F., Walton Lodge, Stone, Staffs. .. .. (1921-22)
SHORTER, C. A., Friarswood, Newcastle, Staffs. .. .. (1906-07)
SIEURIN, E., Höganas, Sweden .. .. (1922-23)
SILLARS, D., Bidston, Britannia Terrace, Saltburn-by-the-Sea (1918-19)
SIMPSON, T. A., Lyndhurst, Wolstanton .. .. .. (1914-15)
SIMPSON, T. G., 34, Elm Street, Cobridge, Stoke-on-Trent.. (1917-18)
SIMPSON, W. A., 27, Kensington Road, Oakhill, Stoke-on Trent .. .. (1916-17)
SIMPSON, E., 35, Pynest Street, Shelton, Stoke-on-Trent .. (1918-19)
SINGH KRISHEN, c/o The Delhi Pottery Works, Rai Sina. Delhi, India .. .. (1921-22)
SMART, H. E., Mountain View, Kidwelly, Carmarthenshire.. (1916-17)
SMITH, H. PROCTER, Hawarden Bridge Steel Works, Shotton, Chester.. .. .. (1916-17)
SMITH, OLIVER, West Hunwick Silica and Firebrick Co., Hunwick, Willington, Co. Durham .. .. (1916-17)
SMITH, F.R., Eastfield, Ironbridge, R.S.O., Salop .. .. (1902-03)
SNEYD COLLIERIES, Ltd., Burslem .. .. (1916-17)
SNOW, WILFRED, R., G.P.O. Box No. 525, Adelaide, South Australia .. .. (1918-19)
SOCIETIE DES PRODUITS CERAMIQUES ET REFRACTARIES, 4, Rue Blanche, Paris .. .. (1918-19)
SOHO POTTERY Ltd·, Elder Works, Cobridge, Stoke-on-Trent (1921-22)
SOMERVILLE, W., The Cottage, Hindlow, Bnxton
SOSMAN, R. B., 2801, Upton Street, Washington, D.C., U.S.A. .. .. (1918-19)
SOUTH METROPOLITAN GAS Co., 709, Old Kent Road, London, S.E. 15 .. .. (1917-18)
SPEIRS, C. W., The Morgan Crucible Co., Battersea Works, London .. .. (1916-17)
STAFFS. CROWN COLOUR Co., 5, Lord Street, Basford .. (1918-19)
*STANLEY, WALTON, 8, Stoke Road, Shelton .. .. .. (1911-12)
STANLEY, CYRIL, Lyndhurst, Shelton, Stoke-on-Trent .. (1921-22)
*STANYER, A., 24, Jenkins Street, Burslem .. .. .. (1903-04)
STANWAY, P. W., Clive House, Clive Street, Shelton .. (1921-22)
STATON, A. D., 37, King's Avenue, Wolstanton, Stoke-on-Trent .. .. (1920-21)
STEAD, J. E., D.Sc., 11, Queen's Terrace, Middlesbro' .. (1916-17)
STEELE, H. L., Messrs. The Britannia Pottery Co., Ltd., 136, Glebe Street, St. Rolox, Glasgow .. .. (1912-13)
STEIN, JOHN G. & Co., Ltd., Bonnybridge, Scotland .. (1916-17)
STEPHENS, ALFRED, Sir, Broomhill, Kidwelly .. .. (1916-17)
STEVENSON, H. W., Royal Pottery, Burslem .. .. (1913-14)
STEVENSON, SAMUEL, 59, Elm St., Cobridge, Stoke-on-Trent (1921-22)

STOTT, VAUGHAN H., 9, Elmers Drive, Teddington, Middlesex.. .. .. (1920-21)
STOURBRIDGE REFRACTORIES Co., Ltd., Pensnett, nr. Dudley .. .. (1916-17)
STOVER, E., 474, West State Street, Trenton, U.S.A. .. (1903-04)
STRINGER, G. E., Wynberg, Newcastle Road, Stone, Staffs. (1918-19)
STUBBS, R., Church Terrace, Blythe Bridge .. .. .. (1920-21)
SURR, M. M., 65/2, Serpentine Lane, Calcutta .. .. .. (1922-23)
SUTHERLAND, W. FRANK, 79, Normandy Buildings, Toronto, Ont., Canada .. .. (1918-19)
SWIFT & NETHERWOOD, Lepton, Fenay Bridge .. .. (1921-22)
SWINDEN, THOMAS, 26, Oak Hill Road, Nether Edge, Sheffield (1916-17)
SWINNERTONS, Ltd., Vulcan Pottery, Hanley, Stoke-on-Trent (1918-19)

TAMS, H., Wharf Street, Longton, Stoke-on-Trent .. .. (1913-14)
TARRANT, W. G., Ltd., Byfleet, Surrey .. .. (1921-22)
TAYLOR, F. E., Trentham, Staffs. .. .. (1913-14)
TAYLOR, J. F., Trentham, Staffs. .. .. (1915-16)
TEALE, JAMES W., 33, Grange Road, Brook Lane, Chester .. (1920-21)
THOMAS, C. W., c/o Messrs. E. J. & J. Pearson, Ltd., Brierley Hill, S. Staffs. .. .. (1903-04)
THOMAS, C. A. G., Clifton House, Old Swinford, Stourbridge (1921-22)
*THOMASON, W., Royal Doulton Potteries, Lambeth, London, S.E. .. .. (1909-10)
THOMPSON, H. H., 52, Lombard Street, Birmingham.. .. (1921-22)
THOMPSON, J. H., The Vicarage, Leek, Staffs... .. .. (1922-23)
THORLEY, J. P., 31, Newcastle Road, Shelton, Stoke-on-Trent .. .. (1920-21)
THRELFALL, C. R. F., c/o Timmis & Co., Stourbridge .. (1920-21)
THURSFIELD, W. T., 41, Stanley Street, Tunstall .. .. (1921-22)
TIDY, CHARLES J., 16, Amesbury Avenue, Streatham Hill, London, S.W. .. .. (1921-22)
*TIMMIS, G. H., Storrage House, Wribbenhall, Bewdley .. (1916-17)
TOOGOOD, H. J., The Poplars, Elland, Yorkshire .. .. (1918-19)
TOOTH, W. E., Claridge House, Woodville, Burton-on-Trent (1913-14)
*TOWNSEND, H., Mount Avenue, Hartshill, Stoke-on-Trent (1909-10)
TRAVIS, W. P., Church Street Chambers, Stourbridge .. (1916-17)
TREDDENICK, WM., 3, Primrose Hill, Newfield, Willington, Co. Durham .. .. (1921-22)
*TURNER, F., Cranleigh, Brampton, Newcastle .. .. (1900-01)
TURNER, Prof., W. E. S., D.Sc., Department of Glass Technology, The University, Sheffield .. .. (1916-17)

UNITED COLLIERIES, Ltd., 109, Hope Street, Glasgow .. (1916-17)
UNIVERSITY OF WASHINGTON LIBRARY, Seattle, Washington .. .. (1920-21)
UNIVERSITY OF CALIFORNIA LIBRARY, Berkley, California, U.S.A. .. .. (1920-21)

VAUGHAN, A. J., Grant Street Colour Works, Burslem .. (1914-15)
VIGGARS, G. H., The Villas, Silverdale, Staffs... .. .. (1922-23)
VICKERS, A. E. J., 27, Lily Street, Wolstanton, Stoke-on-Trent .. .. (1918-19)

WADE, G., High Street, Burslem .. .. (1914-15)
WAGNER, W. G., c/o George T. Holloway & Co., Ltd., 13, Emmett Street, Limehouse, London, E. 14.. .. .. (1922-23)
WAGSTAFF, J. J., 51, Oulton Road, Stone .. .. .. (1921-22)
WALKER, E. E., The Australian Tesselated Tile Co., Ltd., Mitcham, Victoria, Australia .. .. (1916-17)
WALKER, F. W., Art Tile Works, Beaver Falls, Pa, U.S.A. (1906-07)
WALKER, JOHN, The Gate Farm Fireclay & Firebrick Works, Kingswinford, near Dudley .. .. .. (1916-17)

WALTON, C. J., Forsbrook, Stoke-on-Trent .. .. .. (1912-13)
WARBURTON, T. H., The Monk Bridge Iron & Steel Co., Ltd., Leeds .. .. (1916-17)
WARD, T. W., Endcliffe Vale House, Sheffield .. .. (1917-18)
WATERHOUSE, JAMES, Ltd., Soho Works, Wakefield .. (1916-17)
WATTISON, J. T. Rua da Restauraçaõ, 122, Porto, Portugal.. (1918-19)
WATKIN, E., 57, Yoxall Avenue, Hartshill .. .. .. (1916-17)
WATKIN, T., Harding Terrace, Sheppard St., Stoke-on-Trent (1904-05)
WATTS, A. S., Lord Hall, O.S.U., Columbus, Ohio, U.S.A. .. (1910-11)
WEATHERLEY, W. H., c/o C. Tennant, Sons & Co., Ltd., 80/82, Merchants Exchange, Cardiff.. .. .. .. (1918-19)
WEBSTER, J. C., Bridge Pass, Victoria Road, Tunstall .. (1910-11)
WEBSTER, JAS., Lynve, Victoria Road, Tunstall .. .. (1913-14)
WEBSTER, J. T., Shallowford House, near Stone, Staffs. .. (1921-22)
WEDGWOOD, Miss A., The Woodhouse, Cheadle, Staffs. .. (1916-17)
WEDGWOOD, ERNEST, B., The Grove, Wolstanton.. .. (1916-17)
*WEDGWOOD, F. H., c/o Josiah Wedgwood & Sons, Ltd., Etruria, Stoke-on-Trent .. .. (1905-06)
WELLINGTON GAS Co., Courtney Place, Wellington, N.Z.
WELLS, J. H., 10, Glanbrydan Avenue, Uplands, Swansea.. (1916-17)
WENGER, A. F., Victoria House, Newcastle, Staffs... .. (1905-06)
WENGER, A. H., Trentham Priory, Staffs. .. .. .. (1902-03)
WENGER, F. E., The Hollies, The Brampton, Newcastle Staffs (1905-06)
WENGER, T. L., Lawton Hall, Kidsgrove, Staffs. .. .. (1922-23)
WERNER, E. A. R., 174, Corporation Street, Birmingham.. (1920-21)
WHISTON, H. W., 12, Hollings Street, Fenton, Stoke-on-Trent (1920-21)
WHITELEY, A., 7, Glen Road, Netheredge, Sheffield.. .. (1917-18)
WHITELEY, J. H., 11, Cambridge Street, Saltburn, York. .. (1918-19)
WHITFIELD, T. S., c/o The Cobridge Brick Co., Burslem .. (1905-06)
WIDUEMANN, R. E., 30, Rue des Dames, Paris (xvii.) .. .. (1922-23)
WILD, ARTHUR, Hawthorn Dene, Hathersage .. .. (1916-17)
WILEMAN & Co., Foley China Works, Fenton, Stoke-on-Trent (1921-22)
WILKINSON & SON, S., Blackley Fireclay Works, Elland Yorks. .. .. (1916-17)
WILKINSON, A. J., Ltd., Burslem, Stoke-on-Trent .. .. (1922-23)
WILLIAMS, C. P., M.Sc., Flwdwycet, Penrycae, Port Talbot (1916-17)
WILLIAMS, F. R., 1, Beaconfield Villas, Brighton .. .. (1902-03)
*WILSON, S. T., Park Works, Fenton, Staffs. .. .. .. (1904-05)
WILTSHAW, & ROBINSON, Carlton Works, Copeland Street, Stoke-on-Trent .. .. (1916-17)
WINKLE, L. H., Colonial Pottery, Stoke-on-Trent .. .. (1908-09)
WINNICOTT, A. B. (Mrs.), 89, Ditton Hill Road, Surbiton, Surrey .. .. (1918-19)
WITTON FIREBRICK Co., Ltd., Wear Valley Junction, near Darlington .. .. (1916-17)
WONG, W. W., 131, S. Broadway, Los Angeles, California, U.S.A. .. .. (1918-19)
WOOD, A. R., c/o Pilkingtons, Ltd., St. Helens, ... (1920-21)
*WOOD, H. E., Hillside, Hamil Road, Burslem.. .. .. (1900-01)
WOOD, H. F., The Uplands, Brampton, Newcastle, Staffs. .. (1911-12)
WOOD, ROBERT, Quarry House, Dudley, Worcestershire .. (1921-22)
*WOOLDRIDGE, F., Taylor, Tunnicliff & Co., Hanley .. (1905-06)
WORKINGTON IRON & STEEL Co., Ltd., Moss Bay, Workington .. .. (1916-17)
WORTHINGTON, F. S., 5, Havelock Place, Shelton, Hanley (1907-08)
WRAGG, THOS., & SONS, Storrs' Fireclay Works, Loxley, near Sheffield .. .. (1916-17)
WRAGG, THOS., & SONS, Swadlincote.. .. .. .. (1917-18)

WRIGHT, J. E., 153, Cauldon Road, Hanley .. .. .. (1914-15)
WRIGHT, W. T. & Co., Ltd., Sileby, near Loughboro' .. (1921-22)

The numbers in brackets denote the session of election.

Any change of postal address should be communicated to the Assistant Secretary,

A. RIGBY, Pottery Laboratory, Stoke-on-Trent.

Student Members.

ALLDIS, W. A., 4, East Street, Penkhull, Stoke-on-Trent .. (1922-23)
ASH, S., 11, Albut Street, Goldenhill, Stoke-on-Trent .. (1922-23)

BAILEY, W. E., 27, Buccleuch Road, Longton .. .. (1920-21)
BAILEY, W. M. Z., 5, Morley Street, Tunstall.. .. .. (1920-21)
BENNIE, H. DOUGLAS, 15, Gordon Street, Hartshill, Stoke-on-Trent .. .. (1921-22)
BOWERS, J., 67, Albany Road, Birches Head, Hanley .. (1921-22)
BREEZE, T. H., New Street Stores, Hanley .. .. .. (1920-21)
BURTON, W., 50, Havelock Street, Stoke-on-Trent .. .. (1920-21)

DERRY, B. R., Hazelhurst, Blurton Road, Fenton .. .. (1920-21)

HARDING, F. W., 6, Hassall Street, Hanley .. .. .. (1920-21)
HEAP, J. W., 9, Morley Street, Tunstall .. .. .. (1920-21)
HULSE, H., Drubbery Lane, Longton, Stoke-on-Trent .. (1922-23)

JOHNSON, A., 16, Garden Village, Weston Coyney.. .. (1922-23)
JONES, A. E., Lightwood Chase, Longton .. .. .. (1920-21)
JONES, STANLEY CARTLIDGE, 4, Westland Avenue, Newcastle, Staffs. .. .. (1920-21)

MACE, GEORGE, Hillesden, Caverswall Lane, Blythe Bridge.. (1920-21)
MEREDITH, W. DENNIS, 42, Stanley Street, Tunstall .. (1921-22)
MORRIS, J., 4, Foley Road, Longton .. .. (1920-21)

PARTON, LEWIS, 22, Windmill Terrace, Smith Street, Hanley .. .. (1920-21)
PRICE, J., Mount Cottage, Lawton .. .. (1922-23)

RIGBY, S., Church Street, Fenton .. ..
ROTCHFORD, J., 39, Berdmore Street, Fenton .. .. (1920-21)

SHIPLEY, W., Kingsley, Stockton Brook, Stoke-on-Trent .. (1920-21)
STEVENSON, SPENCER, 30, Eagle Street, Hanley .. .. (1920-21)

WARRILOW, H., 7, Bennett Street, Burslem .. .. .. (1921-22)
WHALLEY, G., Jnr., 8, Forster Street, Tunstall .. .. (1922-23)
WHITE, G. J. C., 290, Princes Road, Penkhull, Stoke-on-Trent
WILLDIGG, L. J., Bromley Hough, Garden Village, Stoke-on-Trent .. .. (1921-22)
WILSON, N., Park Works, Fenton .. .. (1920-21)
WOOD, H. F., Uplands, Newcastle, Staffs. .. .. .. (1920-21)

I.—Some Experiences with the Dorr Mill in grinding Quartz and Flint for Pottery Purposes.

By A. S. W. Odelberg.

FOR many years I have held the opinion that the universal practice of grinding pottery materials in batches must be a waste of time and power, since not only is power expended in grinding material already fine enough, but that material is also retained in the mill, where it acts as a cushion and a lubricant, preventing the coarser material from being attacked.

Of course, I was aware that there were closed-circuit tube mills obviating this, but they are dry grinders, and, as a potter, I dislike the dry grinding process for various reasons. Coming over to this country soon after the war, I was, however, agreeably surprised to find a closed-circuit wet-grinding plant, in full operation, employed in the mineral trade. On going closely into the question, I gathered the conviction that this particular process was quite applicable to the pottery trade. The plant to which I refer is the Dorr Milling Plant.

I at once got into touch with the representative in this country, Mr. William Russell, and first arranged with him to have an old cylinder adapted to the process. I was soon convinced, however, that there was little benefit to be derived from putting new wine into old skins, so I ordered and erected an entirely new plant, which could be run without interfering in any way with the old one.

This plant, and my experiences with it, I am now going to describe to you, but at the outset I wish entirely to disclaim any pretention to speak as an expert. Since erecting our plant, I noticed, in the Transactions, that there has been a lecture delivered upon Closed-Circuit Grinding which I naturally read with great interest, but so far, I do not think anybody has given his experience with regard to this process as actually applied to Potters' materials.

Although the plant was erected and ready to start last September, it took me many months to gain the experience and make the alterations necessary to run it for grinding pottery materials on a commercial scale. I had the pleasure of showing the plant in actual operation to those members of the Society who visited me in the early summer, and as I found that they were greatly interested, I arranged with Dr. Mellor to give this lecture and so afford all the members an opportunity of becoming acquainted with it, so far as is possible in this way.

In this particular case the plant has hitherto been solely employed in grinding a mixture in equal parts of calcined quartz and flint.

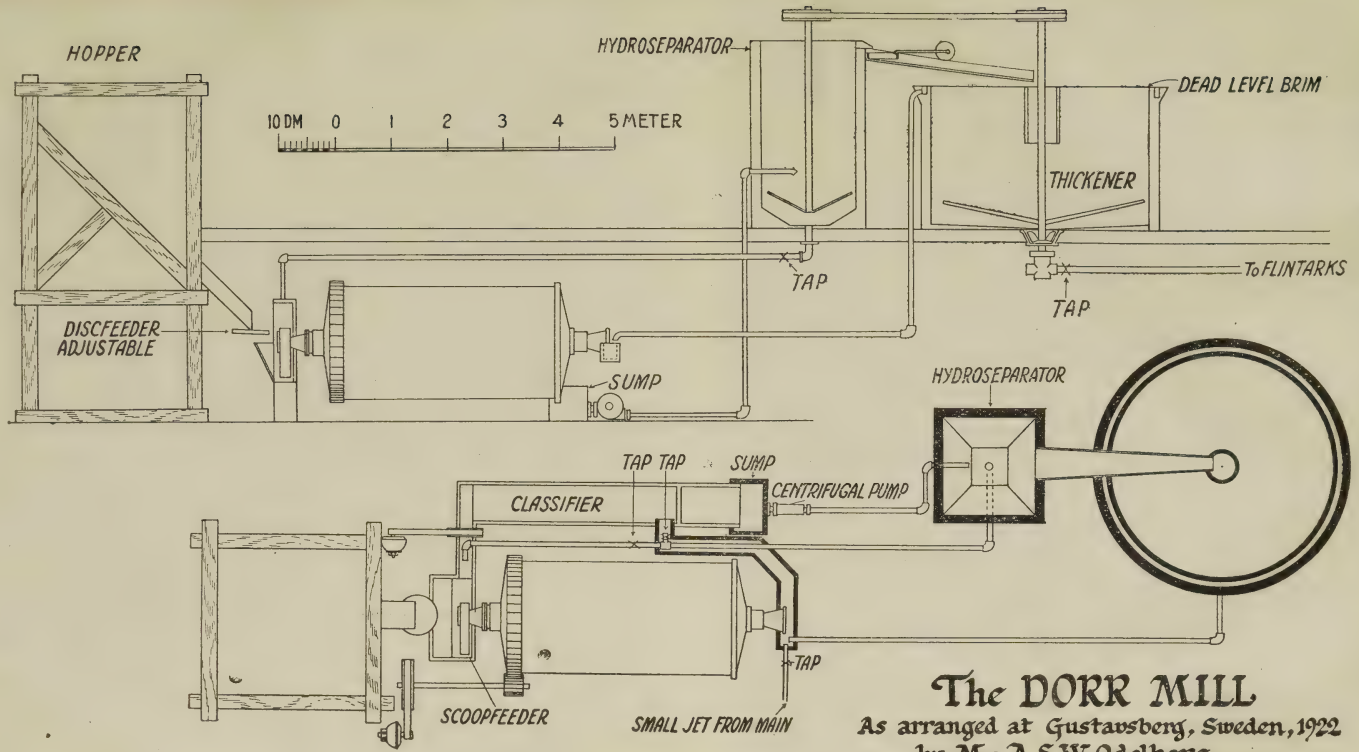
The material is first crushed by means of an ordinary stone breaker fitted with a screen of about 1 cm. mesh, the fragments

not passing through being automatically returned to the crusher by means of an automatic conveyor. Ten tons are crushed in about two hours.

This crushed material is now conveyed to a hopper with a capacity of about 10 tons (see fig. 1). At the bottom of this hopper is an automatic disc-feeder which can be adjusted to deliver the exact amount required. This continuously feeds the material into a trough where it is moistened and intimately mixed with semi-ground material returning from the plant. A scoop feeder, fixed on the rotating shaft of the tube mill, gradually works this mixture into the mill through the hollow shaft by means of a worm. The mill is lined and filled with pebbles in the usual way. At the other end of it there is a hollow shaft, also provided with a worm, which both retains the pebbles and discharges the partly-ground pulp. A strong jet of water pushes this material into what, in the mining industry, is called a launder, which is simply a wooden trough. The pulp, being very much diluted, runs quite freely by gravitation through this trough into the classifier, in which, by means of rakes, the coarsest material is returned to the scoop-feeder to repeat the same round, while the finer pulp flows over into a sump, from which it is lifted by a centrifugal pump to the storey above into a tank filled to the very top with water. This tank we call a hydro-separator, and it acts exactly like a large Schöne apparatus. The coarser pulp runs out at the bottom through an adjustable tap, and it is divided into two parts, one returning to the launder mentioned above, and the other part to the scoop feeder trough to provide the requisite moisture to the material before entering the mill.

The finer pulp flows over the brim of the hydro-separator in a fine film and then passes through a 130-mesh lawn to remove any particles of wood or coal dust. The amount is very small, the lawn requiring to be cleaned only once in twelve hours. The fine pulp now gravitates through a trough into the middle of what is called the thickener, which is a round tank of sixteen feet diameter and about ten feet high, filled to the very brim with water, the top edge being dead level all round (fig. 2). Between this and an outer edge is a groove three or four inches deep, and of the same width, to collect the overflow. This groove is, at a certain point, connected with a pipe which conducts the overflow of practically pure water to the point where it forms the jet, which forces the pulp coming out of the tube mill into the launder and so into the classifier. Thus the circuit is completed, the same water being used over and over again, apart from what remains in the finished slop material, which is run off through a tap from the bottom of the thickener and conveyed by gravitation to the flint ark. To replace the water going away with the finished material into the flint ark, a small jet of water from the main runs into the launder at the discharging end of the tube mill.

A few figures relating to the process will probably be of interest.


HOPPER
HYDROSEPARATOR
DEAD LEVEL BRIM
10 DM 0 1 2 3 4 5 METER
THICKENER
TAP
To FLINTARKS
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SUMP
CENTRIFUGAL PUMP
CLASSIFIER
TAP
SCOOPFEEDER
SMALL JET FROM MAIN
The DORR MILL
As arranged at Gustavsberg, Sweden, 1922
by Mr. A.S.W. Odelberg

Fig. 1.

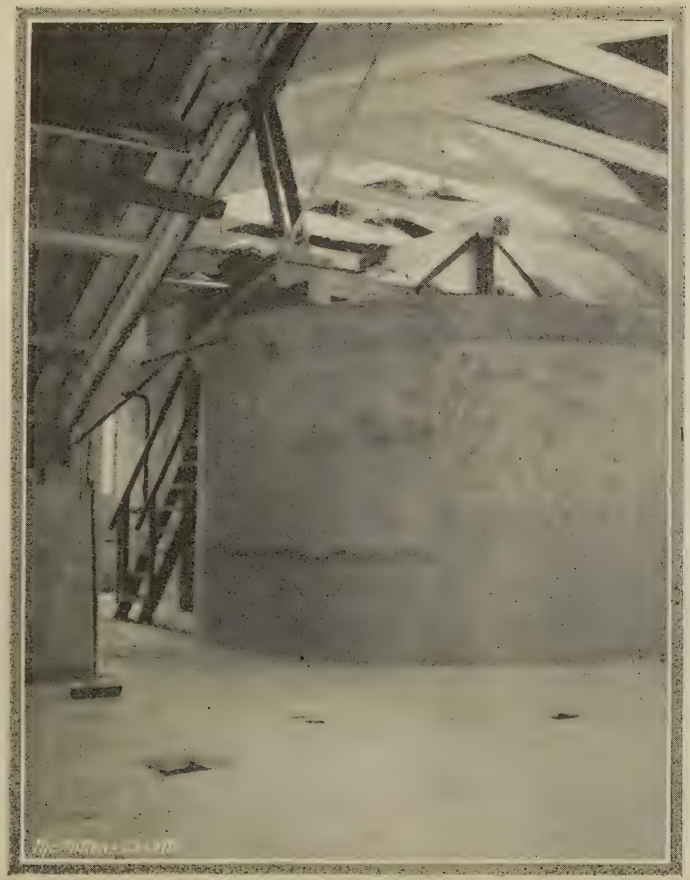


Fig. 2.—The Thickener.

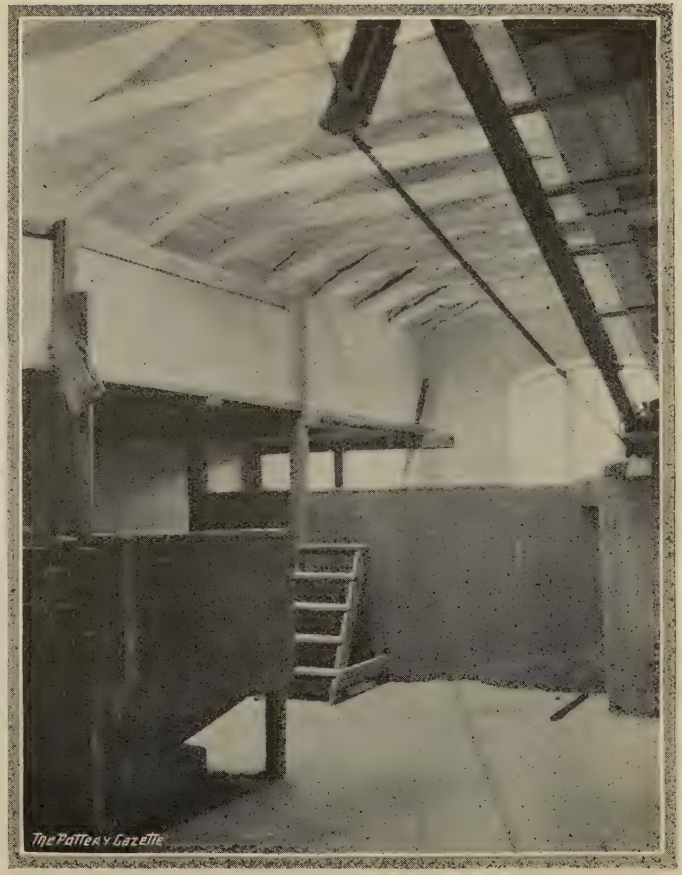


Fig. 3.—The "Dorr" Mill at Gustafsberg.

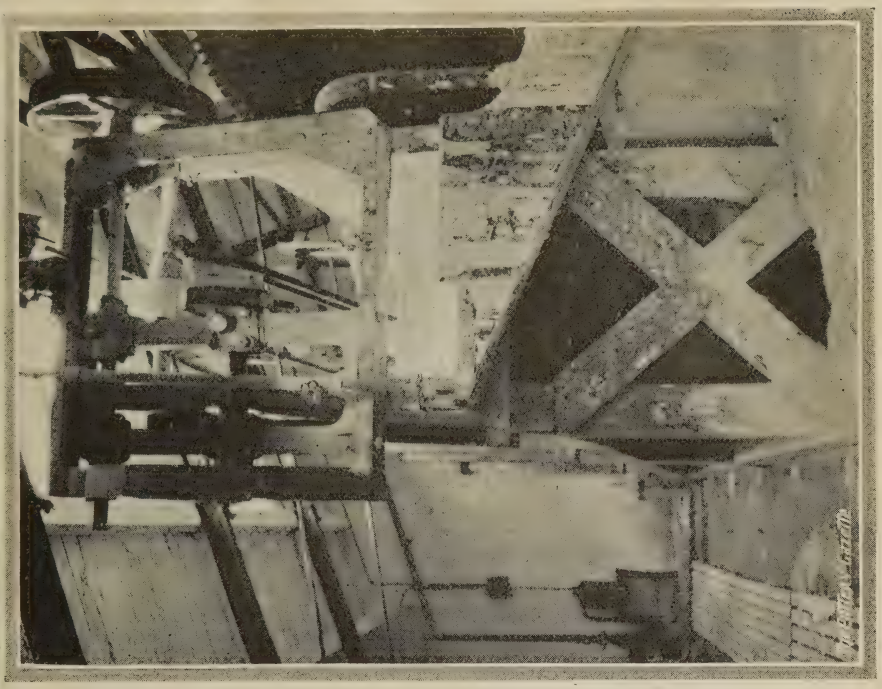


Fig. 5.—The "Dorr" Mill at Gustafsberg.

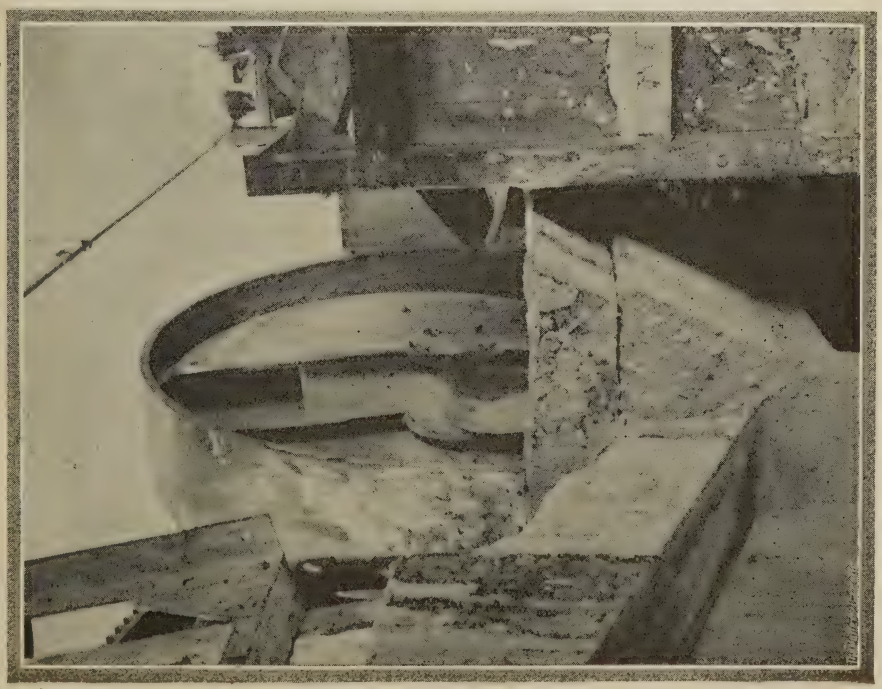


Fig. 4.—The "Dorr" Mill at Gustafsberg.

The rate at which we are grinding at present is about 7·2 tons per 24 hours or about 11 lbs. per minute, dry weight. The thickness of the pulp as it leaves the tube mill is 1·6 sp. gr. or 32 oz. to the pint. To retain this precise thickness is of the greatest importance, as it makes for the smooth working of the mill. To make it thicker would reduce the output, as the flint pebbles then get clogged in the stiff material, and fail to do their work, the actual grinding then only taking place in contact with the lining. This is clearly shown by the ampere-meter attached to the electric motor driving the mill, showing that much less power is being used in grinding. On the other hand, it will not do to dilute the slop material in the mill too much, as the pebbles then sink to the bottom, do not mix with the material, and punish the lining, the ampere-meter showing a tremendous waste of power. This clearly shows the disadvantage of batch grinding, since, at the commencement, you cannot prevent the latter difficulty from taking place, nor, at the finish, the first mentioned trouble from arising. A batch grinding mill functions at its best only during the half-ground stage. Having thus completely overcome these difficulties by means of the circuit grinding process, we reduce the punishment of the lining to a minimum, and the pebbles run as smoothly as on oil, and economise considerably in power, apart altogether from the gain due to the well-known circuit-grinding effect described at the beginning.

The mill is running at 35 rev. per minute, taking about 25 units per hour when the thickness of the pulp is 1·6 specific gravity. The temperature of the pulp leaving the mill is constant at about 60°C., and since the whole grinding process takes place as in an open pan, no air bubbles are retained in the material, as they are in the case of the closed cylinder, which, towards the end, is always grinding under pressure.

By using a hydro-separator, it is possible to get much more washing done in the classifier, this being attained by a much more powerful pump than is usually employed in similar plants. The separation is effected much more quickly. The pump delivers about 200 minute-litres or just under 50 gallons.

The tap under the hydro-separator adjusts the fineness of the grain to any degree required, and the disc-feeder at the feeding end of the plant must be set accordingly. In my particular case, the speed of the water in the hydro-separator rising towards the overflow is set at a velocity of about 0·087 cm. per sec., giving a corresponding fineness of about 60 per cent. of grain-size under 0·01 mm. and 40 per cent. between 0·01 and 0·025 mm. In case only grains under 0·01 mm. are required, the velocity of the water need only be 0·025 cm. per sec., but in that case, you have to feed the mill with less material and content yourself with a reduced output.

Should a coarser material be required, say particles under 0·01 mm. 52 per cent., particles between 0·01 - 0·025 mm. 34 per cent.

and particles from 0·025 - 0·04 mm. 14 per cent., which is generally used in the potting trade, you can easily increase your output to about 10 tons in 24 hours.

My particular reason for grinding finer is simply to counteract the absence of what may be called slime, to the particles of which one cannot assign any measurements. This slime is, of course, always to be found in batch grinding amongst particles under 0·01 mm. diameter.

As my experience is as yet by no means extensive, I cannot say, with certainty, what effect this absence of slime will have on body and glaze; it may be for better or for worse.

To control this plant with speed and certainty, I use my improved elutriator on the Schöne principle, as described in the paper read before this Society in October, 1919*

By making tests with the elutriator, it will be interesting to find how much finished material leaves the tube mill at the outlet, the percentage of fine material leaving the classifier on its way to the hydroseparator, and, finally, to test the efficiency of the classifier so as to see if it returns any ready-ground stuff to the scoop feed.

As you will realise from what has been said, there are many advantages to be gained from using this plant. You get at least five times the output per unit, if not more, compared with batch grinding. In fact, by running night and day, which is now an easy matter by using the electricity supplied by the Swedish Government all over the country, say from Sunday night at six o'clock to one o'clock on Saturday afternoon, this plant, with one cylinder, will do what nine cylinders did, each taking approximately the same amount of power.

The finished article can be obtained of any size of grain required to suit any particular purpose in our trade. The plant being practically automatic, there is a great saving in labour. A man who may be "dog-sleeping" most of his time can exercise all the supervision required, and he could easily look after several units. It is also as nearly fool-proof as possible. You are, so to speak, getting Nature herself to control the process. It is a well-known fact that the best and safest results are obtained when we copy the automatic methods which our great teacher, Nature, uses constantly.

DISCUSSION.

Mr. H. E. Wood:—It is characteristic of Mr. Odelberg that he should be giving us this address on continuous grinding. As for ourselves, we have all heard of these continuous grinders before, and we have talked about them. Mr. Odelberg heard of them too, but he not only talked about them; he went and got one. Evidently he has experienced a good deal of trouble in getting to where he is now with this process, but I know it is the greatest

* Trans., 19, 44, 1920.

pleasure to Mr. Odelberg to overcome these difficulties and he never spares either himself, his time, or his money until he has settled them. As he has shown, it necessitated additional buildings and additional plant, but, having satisfied himself that the system was right, he set about it, and he is now not content that the new apparatus is serving him well, but he is quite willing and, I believe, really pleased to come forward and give us the information that he has gathered, so that we may all get on the right track for doing the same sort of thing. We have all been very delighted to hear what Mr. Odelberg has had to tell us, and I have no doubt he will be pleased to answer any questions which you may care to put to him.

MR. HARTLEY:—Would Mr. Odelberg tell us the internal diameter and length of his tube mill, and the number of revolutions which he considers necessary, as this information might help us.

MR. ODELBERG:—I work at 35 revolutions per minute. I find this the best speed. The measurement inside is just a little under six feet, and the length is about 17-18 feet.

MR. MALKIN:—Can Mr. Odelberg give us the surface factor of the ground material?

MR. ODELBERG:—Yes, that is very easy. In my particular case, as I mentioned in the lecture, the ground material consists of 60 per cent. of particles under 0·01 mm. and 40 per cent. between 0·01 and 0.025 mm. This gives a surface factor of 235.

MR. WM. RUSSELL:—As a guest, I would like to say a word or two on closed-circuit grinding. I would like to congratulate Mr. Odelberg on the success that he has attained with it. He was very courageous to take on a mill that had been previously operating only in other industries and to attempt to apply it to an industry in which there are a great many more difficulties to contend with than in those other industries in which it had been operating, particularly as he did this alone, and, without any help, has made it a success.

He has already told you something about the advantages, but I would like, if I may, to emphasize them. There is first of all a saving of 80 per cent. in the power—nine mills are put out of commission and one tube mill, not much larger than any one of these nine, is able to do the work that the whole nine were formerly doing. There is a great saving, therefore, in labour also. The charging and emptying of batch mills require a good deal of attention. This one tube mill requires a part of one man's time. There is a great saving in repairs. I understand that the nine mills previously in use necessitated the services of a bricklayer repairing practically all his time. In batch grinding, the conditions are not uniform; you have to deal with very coarse material at the beginning of the grinding and an excess of fine material towards the end of the grinding, and in the concluding

stages of the grinding you are actually using more power than at the beginning, this power being utilised very largely to grind the lining. It is one chance in a million that in the later stages you are grinding the coarse particles. Now Mr. Odelberg's tube mill has been running for some time and it has not yet been relined. He tells me that it is still in very good condition.

These are some of the points which occur to me as being real advantages in closed-circuit grinding, and if such advantages exist, surely it is worth while investigating them. Mr. Odelberg has been good enough to style this new plant "the Dorr Mill." As a matter of fact, all that the Dorr Co. supplied was the classifier and thickener which can work in connection with any kind of closed-circuit grinding. It does not even require to be a tube mill. I am inclined to believe that circuit grinding can be applied to mills other than tube mills and with similar success. The main thing to bear in mind is that, with batch grinding, when the bulk of your material is already sufficiently ground and you keep on grinding in order to search for the underground stuff, you are wearing away your lining. The extra power is being put in very largely to do this. If, on the contrary, you can eliminate the stuff that is already fine enough and only utilise the power to deal with material that you require to crush, you are economising your power, saving your lining, and certainly you get a very much greater output from the mill.

MR. MALKIN:—What was the quantity of grinders per 24 hours which Mr. Odelberg found it necessary to introduce?

MR. ODELBERG:—I should say about 3 cwt. of pebbles are used up every day and renewed.

MR. MALKIN:—I have some figures myself, and although I have not taken these on the same basis as the lecturer, I reckoned that, with the old open-pan process, the power utilised is 260 h.p. hours per ton. That shows something in the neighbourhood of 99 or 100 h.p. hours per ton on the cylinder grinding process, and on my elutriation test, which was made at the Pottery School only last month, I had 74 per cent. of what the lecturer would refer to as slime. The question is: is that required by the potter?

MR. ODELBERG:—That is a point which remains to be seen. As I understand it, the old open-pan grinding system gives, on the whole, a very good result when applied to flint grinding, and it is very much the same principle as this, except that it is done in batches. We have made some microscopical comparisons of pan grinding as done in your district with the continuous grinding now in force at our works, and these show very clearly that the result is much the same. As for the slime in the cylinders, it may be an advantage or it may be a disadvantage. I should say from my own experience that it is rather a disadvantage to the potter, and I say this from experience with both open pans and cylinders,

over a period of 27 years, mostly, though, with cylinder batch grinding. It is that over-fine stuff you get in the cylinders which has a tendency towards cracking the ware.

MR. HARTLEY:—I think Mr. Odelberg mentioned in the early part of his lecture that the material is crushed in a preliminary crusher or stone-breaker before it is put into the mill. Can it be ground sufficiently in that way for the purpose without getting in any appreciable amount of iron, and what would be the degree of fineness?

MR. ODELBERG:—I have a sample with me of the crushed material and you can refer to it. It is about half a centimetre in size. As for the iron that may get introduced by the crushing, I find hardly any at all. None can be detected in the samples before you. We get very clean stuff on the whole. Of course, we have a lot of wood in our country, and therefore we can calcine by charcoal or wood. We use wood and we get our flint very white. Ten tons of stuff is put through the jaws in two hours, and when you contemplate the very small amount of iron that is used up in many, many months you will find that it is infinitely small as compared with the amount of material that passes through; in fact, I cannot detect any.

MR. HARTLEY:—You do not use rollers?

MR. ODELBERG:—No.

MR. HARTLEY:—I do not think I have seen any stone-breakers in this country that would break up the stuff into the small sections such as Mr. Odelberg speaks of.

MR. ODELBERG:—That all depends upon how fine you set the jaws.

MR. HARTLEY:—Yes, but I doubt if we have a stone-breaker in North Staffordshire that would do it.

MR. ODELBERG:—We have certainly got them.

MR. HARTLEY:—It seems to me that more iron tends to get into the material by this machine than by the cylinder process. The material has to be fed in by worms and retarded by worms from getting out.

MR. ODELBERG:—In answer to that question I would say that I do not think there is any danger. The tests I have made are exceedingly white. You know that when you pump slip through pipes and similar arrangements you get a sort of coating of the material on the lining through which you pump, and this acts as a protective skin. This, to a large extent, prevents the iron from coming in. The charging end of the tube mill is constantly white, just like a wall that has been painted over with lime. The racks are all covered with slop flint. You can see that very clearly in the photographs. I do not think there need be any fear as to iron

getting in at all. I think you get more iron in by the old pan method, where you have those iron arms moving round in the grinding pans.

MR. WOOLDRIDGE:—I would like to substantiate Mr. Odelberg's remarks about getting in less iron. We have had a continuous mill at work for six months and the iron content in the slop material is considerably less.

MR. ODELBERG:—In our cylinder grinding I found that when you start a mill with new pebbles it really does not work properly for many months because of the regular size of the pebbles. In our case we simply put in about 3 cwt. of pebbles every 24 hours, and these are just about the size of an ordinary tumbler.

MR. HARTLEY:—But the small ones break up altogether and get into the body.

MR. ODELBERG:—They wear off the surface.

MR. PODMORE:—I would like to ask what is the capacity of the settling tank?

MR. ODELBERG:—It is sixteen feet in diameter, and about 10 feet high.

MR. PODMORE:—What tonnage will it hold?

MR. ODELBERG:—We do not keep much in the thickener. We have only about a layer of not more than two feet at the bottom. It is constantly working out. We do not want to have much for several reasons. For instance, when the material is standing over a Sunday it is more difficult to start the agitators scraping the bottom. For that reason, there is, on the Dorr mill, a lifting apparatus so that you can lift up the agitator to the top where the thick layer begins and screw it down to prevent the shaft being broken on restarting, when it is covered by the settling flint. Otherwise it might have a tendency to break.

MR. W. E. GOODWIN:—Does Mr. Odelberg stock any of this ground flint or does he turn it as soon as possible into clay?

MR. ODELBERG:—We generally stock our flint for three or four days, and by keeping the agitator moving slowly I can keep it exactly at 30 ozs. to the pint. We have found it advantageous to stock it for a little while. It all depends upon how busy we are.

One reason why I have been particularly glad to have your questions is, that four eyes can always see more than two, and it is nice to have one's methods criticized by one's friends. It is always an advantage to compare notes, and I am always glad to let you know how we do things over in my country, because you may not only learn something from us but also we may learn something mutually.

II.—Continuous Grinding.*

By C. J. Møller.

ONE of the few purposes in the manufacture of earthenware and china goods for which mechanical power has been used many years, is the crushing and fine grinding of the different hard, raw materials. For this purpose it has always been necessary from the first to have some mechanical power, whereas the other processes in the industry, such as turning, firing, glazing, etc., were based on the skill of the workmen, accumulated for several generations, and on the ability of the chemist, who had to prepare the different mixtures for the production of the best body.

For this reason there has been, from a mere mechanical engineering point of view, less call for improvements in this industry than in others, as the power consumption in the small potteries of earlier times was comparatively low, and so it did not pay to make extensive alterations for saving power.

For about 150 years, pottery making was the only industry of importance, in which the grinding of hard raw materials to great fineness was used on a large scale, and it is only for about 50 or 60 years that other industries have required such grinding of hard materials to a similar extent. At present this takes place more particularly in the manufacture of cement and in the refining of various ores. During the last 50 years, these two latter industries have developed very rapidly, and as they depend principally upon an economical grinding of the materials, it has been necessary to look very carefully into the question of economy and labour saving in the grinding process, and, consequently, great improvements have been made therein.

Before going too far into the matter, however, I would like to mention the conditions required for fine grinding in the three different industries, and these are the following :—

For the refining of ores—iron ore, gold ore, etc.,—it is essential that the grains of the finished, ground product are of a uniform size, so that the grains of gold ore, iron ore, etc., can be separated from the rest of the material by a process based on the specific gravity of the different materials and on the size of the grains. Consequently, continuous grinding is used here, followed by a separation in classifiers, so that grains of about the same size are carried to the same machine, the grains with a higher specific gravity being separated from those with a lower specific gravity.

In the cement industry, however, as much fine powder as possible is wanted among the comparatively coarser grains, so that all sizes are represented, from those passing lawn 180 down to the very finest product, and according to the information Dr. Mellor gives in his papers, a similar composition of the ground materials

*Read before the Ceramic Society at the Royal Technical College, Copenhagen, in June, 1922.

has proved to be the best for the pottery industry, but with a somewhat greater fineness, viz.: about 50 per cent. or more of fraction A, where fraction A represents grains smaller than 0·01 mm. diam., and only about 0·2 to 0·3 per cent. left on mesh 180.

From this it will be seen that the machinery used for the grinding of iron ores is not the best adapted for potteries, whereas the machinery used for the manufacture of cement might possibly be used, or at least comparisons might be made between the machinery for cement works and that for potteries.

In the cement works the grinding always takes place continuously. Two machines are ordinarily used; firstly a Kominor, an improved ball mill with steel lining and steel balls, in which the raw materials for cement and also clinker from the kilns are ground to pass mesh 10 or 12. It has proved necessary to divide the grinding into two steps or more, and it is the preliminary coarse grinding down to mesh 10 to 12 which takes place in the Kominor, the fine grinding taking place in a tube mill, a continuously working mill, originally provided with silex lining and flint pebbles, and later on improved by other linings and grinding bodies, but, in the main, of the same design as the tube mill.

The tube mill for cement grinding generally grinds the material down to about 10 per cent. left on mesh 180.

With this division of the grinding process in the cement industry as a basis, F. L. Smidth & Co. investigated the same question with regard to potteries. They found that it proved to be the best way to work on a similar principle in potteries, carrying out the preliminary crushing and the fine grinding on different types of machines, thereby obtaining the most economical grinding.

It is, however, impossible to grind potting materials in a Kominor, as the grinding with steel balls in a steel-lined chamber would introduce so much iron into the material, that it would be very difficult to purify again. The material for potteries must therefore be given a preliminary grinding, either in an ordinary edge runner, or in an ordinary double roller mill. The grinding in a double roller mill costs less in manual labour and power consumption, and the crushing takes place continuously, as the material is fed to the mill from a feeding device so that no attendance is required. The power consumption of an edge runner is considerably greater.

From the double roller mill the material passes automatically to a rotary sieve, where the grains, which are too large, are retained and returned for renewed crushing in the roller mill.

As mentioned before, a saving can be obtained by introducing roller mills instead of edge runners for the preliminary crushing. However, it is mainly with regard to the fine grinding that the experience from the cement industry has proved to be useful for solving the corresponding problem in potteries. In the cement industry it has been shown that the best result, with regard to power

consumption per ton of material ground, is obtained when the tube mill—or cylinder mill—takes the greatest possible power consumption per ton of material and per ton of pebbles charged into the mill. This means that it is necessary to fill the mill with pebbles and material in such a way that the mill runs at the highest possible horse-power. Economy will then be obtained by a simultaneous reduction in the grinding time, which is decreased to a minimum.

Elaborate tests have been carried out in our laboratory and at potteries to try to find these figures, and it appears that a fine grinding to about 52 per cent. left of fraction A, (grains less than 0·01 mm.), with a grinding time of about two hours, ought to give the best result with regard to H.P.-hours per ton of ground material, as well as with regard to output per mill per hour. With a mill containing about 11 cwt. of calcined flint, a charge could be ground in two hours with a power consumption of about 25 H.P., so that the total power required for the fine grinding was about ·90 H.P. hours per ton of calcined flint. The cylinder is 5′ diam. by 6′ in length, and should thus be able to grind 4 cwt. per hour or 1 ton in 5 or 6 hours, including the filling and emptying operations.

These are not the ordinary results obtained with mills in potteries where the mills are generally running from 12 to 24 hours, but as F. L. Smidth & Co. have great experience with regard to grinding hard materials in other industries, these results induced us to take up the problem of fine grinding in potteries, and, having once attained the results mentioned here, it became clear to us that it would be possible to revise the grinding process in potteries to a great extent by making use of our special knowledge on this subject.

There were, however, different questions which we had to consider in order to arrive at a satisfactory solution of the problem. These may best be indicated by considering the general layout of a pottery grinding plant based on our system.

The hard raw materials, flint, felspar, stone, etc., are first crushed in an ordinary jaw crusher, from which they are taken up by means of a belt bucket elevator to a bin above a feeding device. The jaw crusher is of ample size so that two men can fill it continuously, thus in a short time filling the bin over the feeding device. The preliminary crushing plant now runs automatically without any attendance until the bin is empty, when it must be filled again, by the men, through the jaw crusher. From the feeding device the material enters a roller mill with special hard-steel roller shells for avoiding wear, and from here the material, crushed down to pass, say, mesh No. 10, passes a magnetic separator and is lifted up to a rotary sieve. From the rotary sieve, the material, ground sufficiently fine, passes on to different bins, one for calcined flint, one for felspar, one for stone, etc., whereas the coarser particles run back to the roller mill for renewed crushing.

There is another point to which I wish to call your attention,

namely, that in the manufacture of cement it has been found necessary to grind the hard and soft materials together in order to get the very best mixing, and, judging by tests carried out in potteries, it appears that the same applies to this industry, even if not to the same extent as in the cement industry. We therefore based our plants on mixed grinding of the raw materials ; the hard materials are weighed out from the different bins in the correct proportions for one charge of the mill, and ground down for about 2 hours with the necessary amount of water. The soft materials (clay, china clay, etc.) are filled in, and all the raw materials are ground together for a quarter of an hour to half an hour, after which the whole contents of the mill are emptied out as ordinary slip.

In this way the weighing out of the different raw material takes place dry, and thus, various sources of errors are avoided, for instance, incorrect specific gravity of the slip and wrong filling into the mixing basins. At the same time, a very thorough mixing of all the raw materials is obtained, and, further, this slip appears to be more uniform in its composition than the slip obtained by mixing up the raw materials in a mixing basin.

From the mill the material passes over a magnetic separator and a control screen where impurities are retained, and from here we ordinarily run the slip down into big, reinforced concrete hoppers, where it is stored for some time, as it appears that a maturing of the slip takes place when it is kept as a well-ground mixture for some time in big storage basins. To avoid precipitation, the slip is kept agitated from time to time by means of compressed air blown through it.

The filter pressing takes place in the following way : The slip runs by gravity from the reinforced concrete hoppers down into sheet iron receivers, from which it is forced into the filter presses by means of compressed air. In filter pressing by compressed air, the necessary time is reduced to about half the time ordinarily required for this operation, and at the same time the composition of the filter press cakes becomes more even, as no blows from a piston reach the slip ; and further, the durability of the filter cloths is prolonged, as the blows from filter press pumps seem to have a bad effect on them.

As mentioned before, we are using continuous grinding for the cement industry, but for pottery purposes, we have always recommended intermittent grinding. We arrived at this conclusion after finding it impossible to grind the material down to the necessary fineness at once in a continuous mill. For continuous grinding it will be necessary to install a classifier, but as we grind the different raw materials together, this means we cannot be sure that the correct composition of the slip is maintained. We have, therefore, come to the conclusion, that quick intermittent grinding is best adapted for potteries at the present stage.

At the different potteries and porcelain works which you will

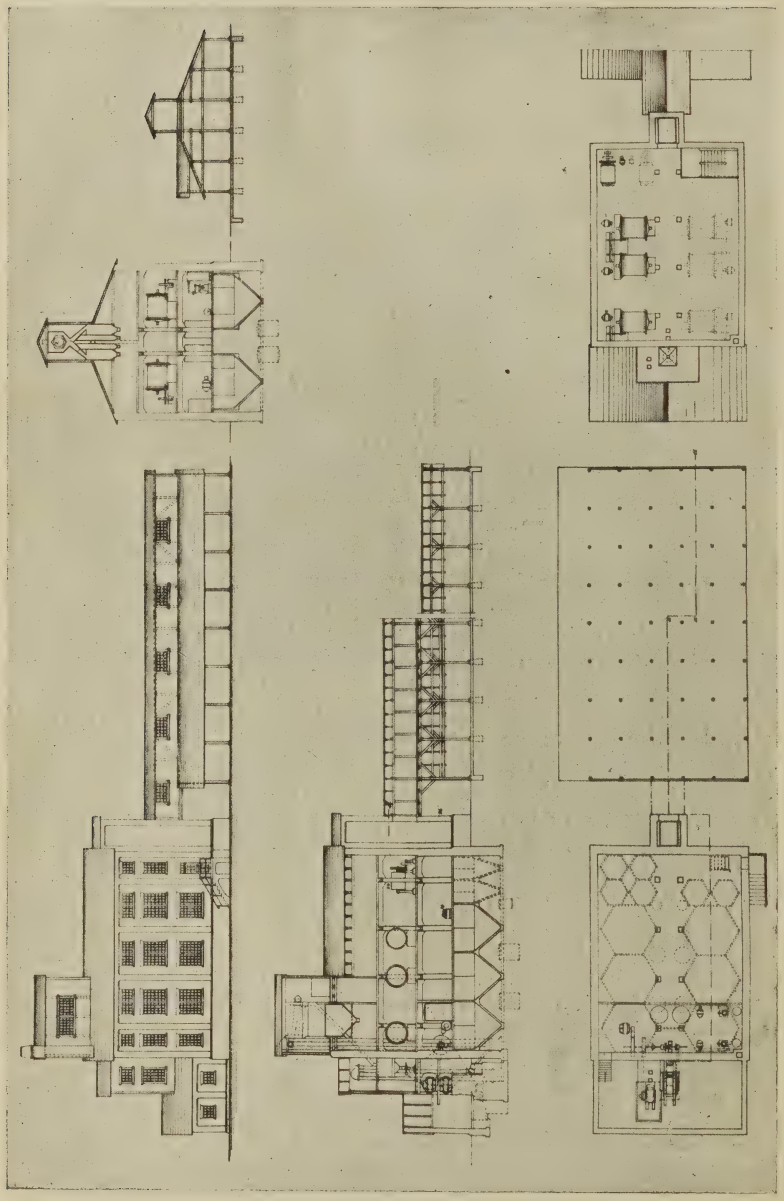


Fig. 1.

visit here, you will see this system used to a certain extent, so that you can get a fairly good idea regarding the working of this type of plant from the information I have given here and from the plants which you will see. Fig. 1 gives an idea of the method of laying out the plant.

When, more than ten years ago, we started our work on grinding plants for potteries, we soon realised that there were many difficulties to overcome, before the system would be ready for recommendation to our customers. With regard to our investigations of the grinding problem, I would like to point out that we were not always sure of the results obtained with our elutriation tests, and therefore, we had to alter our ordinary arrangement to ascertain the very best working of the elutriation devices.

Fig. 2 is a photograph of our elutriation device.

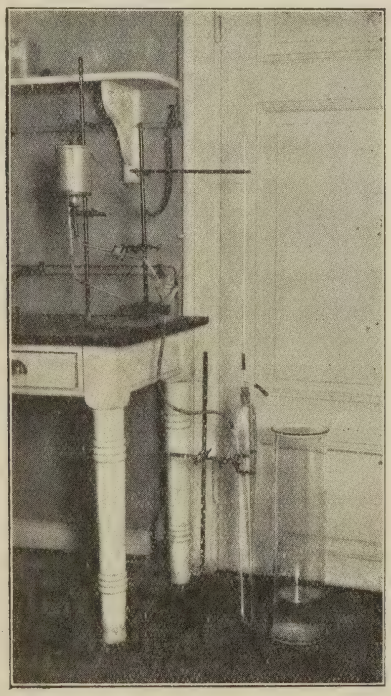


Fig. 2.

The water flows from the pipe into a small vessel, and then through a rubber piping and a nozzle. An overflow is fixed to the vessel, and, by the difference in height between the overflow and the nozzle, the quantity of water passing per minute is absolutely

fixed. Trials have to be made to get the right quantity from the nozzle. The water then passes the funnel, and, as the diameter is measured very carefully, the velocity of the water through the funnel determines directly the size of grains washed away.

In addition to the process described above, there is another place in the potteries where grinding has to take place, viz. in the manufacture of saggars, where old saggars must be ground and the grog mixed with raw clay.

In order to make a good concrete, the cement, sand and gravel must be mixed dry, and from this rule we have worked out layouts for the manufacture of saggars following the same principle. Moreover, it is essential that the surfaces of the different grains of grog should be as large as possible, and therefore, the crushing must take place neither in a ball mill nor in an edge runner, but in a roller mill, where the sharp edges of the grains of grog are retained. A plant working on this principle will be as follows :—

The old saggars are crushed in a jaw crusher and passed from a feeding device through a roller mill, the grog being separated into different sizes in a rotary sieve (Fig. 3). At the same time, the

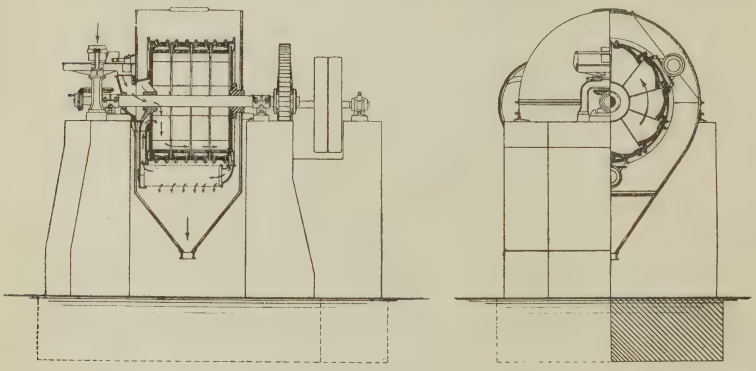


Fig. 3.

different plastic materials, fire clay, china clay, etc., are ground dry in a disintegrator or some other suitable mill, and the five or six different materials are measured out automatically in a dry state. They are mixed thoroughly in a dry state; water is then added, and, after maturing in soaking pits, the saggar material is finally pugged and mixed.

The whole plant works automatically, so that no attendance is necessary, except for filling into the disintegrator and jaw crusher, as well as for taking the material from the soaking pits to the pug mill. When you visit the different works, you will also get an opportunity of seeing plants working more or less on this system.

I am sorry that time does not allow me to give you further information regarding our grinding plant, but I wish to point out,

that what the firm F. L. Smidth & Co. has tried to do with regard to the grinding process in potteries, is to apply their experience in fine grinding, gained in other industries, to the grinding plants of potteries, and to work out an improved system. It was essential for them to ensure that the finished slip was always the same, day after day, and to obtain this with the smallest possible power consumption per ton of finished slip, thus reducing the amount of manual labour and night work ; they were also required to produce a finished slip which was best adapted for the later stages of the pottery manufacturing process.

III.—The Danish Ceramic Industry.*

By Prof. Carl Jacobsen.

IT is my task to-day to give you a general account of the Danish Ceramic Industry, of the manner in which it has developed, and of the more important of the wares it has produced. In the very limited time at my disposal, I must confine myself to giving only a rough outline of a vast subject; details must perforce be omitted.

A study of the geology of Denmark at once reveals the great difference between this country and Sweden. There, as you will have noticed, the solid rocks are, as a rule, quite visible at the surface, whilst in this country they have been for the most part covered with vast deposits of clay and gravel. The only exception to this is the little island of Bornholm, to the geological nature of which I shall return later. Boring operations, carried even to the greatest depths at various places all over the country, have yielded evidence of comparatively recent sedimentations only. Layers of chalk and limestone, formed in the chalk age many hundred metres in thickness, are covered with deposits of clay of tertiary formation, which had their origin during the ice age. This means, from a ceramic point of view, that there is small chance of finding in this country the more valuable ceramic raw materials, such as china clay, high-grade refractories, white-burning plastic clay, and last, but not least, coal. Except at Bornholm, these materials are nowhere to be found in Denmark, which country must, indeed, be considered poorly provided to be a homestead for the manufacture of, at any rate, the more refined ceramic wares.

For the production of the coarser products conditions are perhaps more favourable, clay suitable for bricks, even if not of very good quality, being found in large quantities all over the country. Denmark is, and always has been in the past, a country where bricks have been the national material for building purposes, owing to the fact that wood and stone are available only in limited quantities within the borders of the State. There is no doubt that brickmaking was introduced into Denmark with Christianity, and the use of bricks has always been the main characteristic of Danish architecture. A visit to our town hall will serve to illustrate the great beauty which a modern Danish architect has been able to create with bricks.

The Danish brick-making industry is based almost exclusively upon the use of quaternary clay, which was transported to our country by the enormous glaciers coming from the Scandinavian

*Read before the Ceramic Society at the Royal Technical College, Copenhagen, in June, 1922

peninsula. The clay is found in huge moraines deposited by the melting ice. It is evident that such moraine-clay, located in its original stratum, must be mixed with much gravel and stone, owing to the remarkable capacity of the glaciers to convey materials of practically every size. Such stone-mixed clay, as you know, cannot be used for brick-making until all the pebbles have been removed by washing, a process of somewhat doubtful commercial practicability with a product as cheap as ordinary bricks. Only in cases where the bricks can be made and transported with exceptional cheapness, *e.g.*, in the neighbourhood of Copenhagen, has it been found possible to utilize this moraine clay. The greater portion of our brickmaking industry depends upon the use of stone-free clay, that is, clay which has been deposited in lakes formed by the water from melting glaciers, and which has therefore passed through a natural and very intensive washing process. Deposits of such clay are very common all over the country ; as a rule they are rather thin, being only a few metres in depth, but they are often quite extensive,—large enough to provide a brickworks of ordinary size with an annual production of, say, ten million bricks with clay for a considerable period. This raw material is, as a rule, fairly homogeneous, with very few pebbles and fossils or "shells." Its plasticity is not very pronounced, owing to the high content of sand and chalk, of which substance as much as 30 or 35 per cent. is often found in the clay. Chalk, as you know, affects the colour of the bricks very materially. If the amount of carbonate of lime present in the marl is three times that of iron oxide, the bricks will have a yellow colour, but if it is less, their colour will change to red. Now, in the upper part of the deposit, the chalk will naturally have been washed away by the penetrating water, and this somewhat distinctive layer is quarried and collected separately, to be used for best red face-bricks. The bricks are moulded by machinery, usually by the plastic process, recourse being made to pug-milling and wire-cutting. The clay is kneaded in a mixer, which works as a feeder for the pug-mill, the latter being always of the horizontal type and often with two pairs of rollers, of which the upper breaks up the pebbles, while the lower reduces the coarser particles. The clay passes through a water-cooled mouthpiece and over a cutting table, where the clay strip is cut transversely by a wire fixed in the frame, three bricks being, as a rule, cut simultaneously. In very isolated cases the cutting tables are worked automatically. The moist bricks, containing nearly 30 per cent. of water, must now be dried, which process, a few years ago in particular, always took place in open sheds, where the bricks were placed on shelves exposed to the wind. Such a drying process is dependent in the highest degree upon the climatic conditions, and as the damp bricks must on no account be exposed to frost, the operation is limited to about twenty-five weeks, with an average drying period of about a fortnight. Artificial dryers are,

of course, often employed here; but though it is so very desirable to accelerate the drying process and render it more independent of weather conditions, it must always be remembered that most of the Danish clay cannot stand quick drying without cracking. The best method is undoubtedly to utilize the waste heat from the kiln for drying the bricks. This method can be seen in operation at Hedehusene, where there is one works of the older type, without artificial drying, and also a modern one, typical of the installations with hot air drying, such as have been constructed by Messrs. F. L. Smidth in many places in Denmark and Sweden. The dried bricks are always fired with coal, or more seldom, with peat, in continuous kilns of the oblong Hoffmann type. The quantity of coal used is about 5 per cent. of the weight of the bricks. The burning temperature is usually from 950 to 1,000°C.

These bricks, of which the 200 works of the country produce, in normal times, from four to five hundred millions annually, have a crushing strength of approximately 125 kg. per square cm. for the lighter fired bricks, and 185 kg. for the harder fired. In addition to bricks, the works also produce roofing tiles and drain pipes, similar varieties of clay and technical methods being employed. Roofing tiles are now, however, generally made from the moist and plastic clay by pressing between plaster of Paris moulds in a power-driven press. For the production of clinkers, stoneware paving-stones and similar ware, the ordinary clay is quite unsuitable, its sintering and melting points being much too close together. The special geological structure of the island of Bornholm is entirely responsible for the few instances in which the production of clinkers from Danish materials only has been found possible.

From a geological standpoint, Bornholm resembles the Scandinavian peninsula far more closely than the rest of Denmark. All over the eastern portion solid rocks are visible at the surface, while to the west of these, Cambrian-Silurian formations, with sandstone, etc., make their appearance. Still further west, branches of the Høganas deposits reappear, which consequently contain both refractory clays and coal. The latter formation opened up possibilities of establishing a ceramic industry in Bornholm similar in character to the world-famous centre at Høganas in Sweden, but for a number of reasons,—chief among them being the fact that the Bornholm coal is so scarce and of such poor quality, that mining operations would not be remunerative,—the island industry assumed a much more modest character than in Sweden. In one respect only is Bornholm better provided than Skaane, namely, in that it possesses a fairly large deposit of pure china clay, which has proved of importance in various ways to the Danish industry. It extends for nearly three kilometres along the north-west border of the rocky territory, forming a girdle 100 metres wide and from six to forty metres in depth. It is covered with moraine clay of from four to twenty-five metres in depth, which has to be removed

before the china clay can be quarried in open pits. It is, undoubtedly, the remnant of a once very extensive china clay formation, which probably had its origin in the palæozoic age, or possibly in the early mezozoic era, but which, for the most part, was swept away later on, mainly by the glaciers which passed over the island during the ice age. The Bornholm kaolin is, without doubt, the result of the decomposition of granite, of which the surrounding rocks are formed. This decomposition was not, as in Cornwall, brought about by an outburst of vapour from the interior of the earth, but by percolating water, the process being materially augmented by a hotter climate than the present. The china clay contains the original quartz grains of the granite in their primary position, quite unchanged and easily removable by washing, after which the clay emerges as a very pure, unmixed variety, not unlike the well-known Zettlitz kaolin, except that it contains a little more iron. It was formerly used for making china, but is now no longer employed for this purpose, since it is too ferruginous to produce an absolutely white porcelain. Nowadays, it is used for earthenware, in the manufacture of paper, and finally for mixing with fireclay to make refractories, clinkers and saggars.

Fireclay of a good, though not of the very best quality is found in many localities in Bornholm. Like the corresponding formations in Skaane, these deposits were formed in the later jurassic age and in the early trias period, and were later covered with a rich vegetation, which no doubt explains the absence of alkalies, an important consideration in relation to the use of the clay for refractories.

Some years ago the refractory industry of Bornholm consisted of several rather small works, but these have now been amalgamated into one large concern, Bornholms Kaolin, Klinker og Chamotte Fabrikker, with works at Hasle and Rønne. This firm is concerned chiefly with the manufacture of refractories, both with and without grog, and in some cases with the addition of raw kaolin; they also make "Klinker," or paving stones, which have been shown by scientific and practical tests to be highly resistant to wear and tear.

Another small island in a different part of the country contains a raw material upon which is based the production of a peculiar and interesting ceramic product. On the island of Mors, in the Lunfjord, a diatomaceous earth, formed in salt water during the tertiary age, is found in large quantities. A characteristic of this particular formation is its somewhat high clay content, which, as a rule, almost reaches 10 per cent. For ordinary purposes, such as the manufacture of dynamite, for insulation, etc., this material is simply injurious, since the clay renders the substance heavier and less porous, and for a long time it was considered impossible to make any practical use of the "moler," as it is called in Danish. At the suggestion of Professor H. J. Hannover, of this college, F. Møller made a series of tests, some years ago, on firing bricks of this material. He found that it was very suitable for the purpose,

being easy to form and easy to fire in ordinary kilns. The bricks were very porous, and consequently very light, but they possessed the remarkable property, considering their high porosity, of great mechanical strength ; with a specific gravity of 0·9, their crushing strength was 150 kg. per sq. cm., quite as high as that of ordinary Danish marl bricks. As might be expected of so porous a material, the heat insulation factor is very high, being three times that of ordinary bricks. Moler bricks are very suitable for many building purposes, being easy to transport and handle, but their most important application is for kilns, where the insulation factor is of great value. The new Moler industry is already considerably developed, and export is increasing. Two factories in Eierslev and Skarehage now specialize in this branch of the industry.

Hitherto, I have discussed only the manufacture of bricks and similar products for building purposes, made of clay of the simplest kind. But this clay is also used in making common pottery, more or less coarse, though in some cases, of artistic merit. Ware such as this was produced even in the flint age, and in the tombs of that period evidence is found of quite a high standard in this craft. Probably there is a direct connection between this ancient pottery and the production of Jute-pots, a domestic industry of considerable ceramic interest. The purpose of this industry was the production of quite simple household ware, plain, black, unglazed pots, made by hand without the use of the potter's wheel and always the work of women. It was dried slowly and finally fired with peat in a hole dug in the ground. A strongly reducing atmosphere was thus obtained, which led to the deposition of much carbon in the porous body. For centuries this ware was used all over the country to the widest extent for preparing all kinds of food, and it was also exported, *e.g.*, to North Germany. Competition with enamelled hardware has now, however, caused this industry to die out.

My time is too limited to deal in further detail with the Danish common pottery industry, represented by about forty small works, which turn out both glazed and unglazed wares. Of far greater interest is the artistic ware, with a porous body, which by close co-operation with native artists of distinction, has now attained a high standard. I need only mention Herman A. Kaehler, of Noested, and P. Ibsens Enke, of Copenhagen, who are highly esteemed, both here and abroad, for the beautiful outlines and pretty glazing of their wares.

I will now endeavour to give you some idea of the manufacture of fayence in Denmark. Fayence may be defined as earthenware, consisting of a white porous body covered with a transparent lead glaze. As is the universal practice in this country, all the lead is contained in the frit. It is not possible for me to mention all the numerous attempts during the seventeenth, and the earlier part of the eighteenth, centuries to open out factories in Denmark for

earthenware of the Delft pattern, and later on of the English type. Only in isolated cases did they achieve satisfactory results, specimens of which may be seen in our collections. They are greatly valued by connoisseurs, but they have never been the basis of a more important industrial development.

Modern Danish earthenware is produced at the "Aluminia" Works, which are associated closely with the Royal Porcelain Works. The concern is now known as the "Copenhagen Fayence Factory"; it was founded in 1863, on quite a small scale, in Christianshavn, labour being supplied by convicts from the State prison, and was transferred, in 1869, to its present site in Frederiksberg. In the previous year the management had been taken over by the most prominent leader in the Danish ceramic industry, Philip Schou, an engineer of this College. Among other reforms, he introduced one which was exceedingly audacious for his time, namely, the firing of biscuit ware in a newly erected, continuous, gas-fired Mendheim kiln, undoubtedly the first of its kind to be used for this purpose. For many years the firm's speciality was the production of ordinary household ware, and by the end of the seventies it had secured a good market for its produce in Denmark. A more significant development, however, has been the attempt, made of late years, to produce artistic earthenware, and "Aluminia" has succeeded in creating a peculiar style of great beauty. As a consequence of this development, it has been found necessary to enlarge the works considerably, but the scheme was very seriously retarded by the war and is not yet quite completed. I will only mention that the grinding is now done in ball-mills, working on the batch-grinding system in a grinding department, constructed in a new and original way by Messrs. F. L. Smidth & Co. I need scarcely point out that a Danish concern such as "Aluminia," which has always made it a point of honour to produce felspathic earthenware of the highest quality on English lines, has been obliged to carry on an uphill fight against the competition of the inferior and cheaper German chalk fayence, especially as both labour and coal are more expensive here than in Germany; and the tariff only affords slight protection. The future of the works will, undoubtedly, be mainly dependent upon the production of artistic earthenware. Fortunately, "Copenhagen Fayence," with its sign of three wavy lines traced horizontally across a large "A" is so well known the world over, that we may confidently hope that the future of this comparatively new, but already nationally distinctive ware, will be bright and prosperous.

In one respect at least, the "Aluminia" earthenware works have played an important rôle in our Danish—and perhaps I might venture to add, in the international—ceramic industry. It was by the intervention of this concern that the century-old Royal Porcelain Works were rescued from extinction. In his interesting book: "Royal Copenhagen Porcelain," Mr. Arthur Hayden has

told the story of the changing fortunes of this factory in a fascinating way. I need only mention that, after several failures, the French ceramist, Fournier, in the service of King Frederick V., succeeded, in 1760, in making a soft paste porcelain, of which very few pieces, greatly valued by collectors, remain. After the death of the king, the management of the concern was handed over to the young guardian of the Copenhagen mint, Franz Heinrick Muller, who very soon proved himself a master potter of the highest ability. Within a short time he raised the standard of work considerably. For the first year of his management the works were run as a private concern, but in 1779 they were taken over by the State. Wherever porcelain was appreciated, the new mark of the factory, the three wavy lines, invented by the dowager Queen Juliane Marie to symbolize Oresund, Storebaelt and Lillebaelt, very soon won renown among collectors. The work turned out during the period of Muller's management, *i.e.*, from 1775 to 1801, of which an exquisite collection may be seen at the Museum for Applied Art at Copenhagen, is of the highest order, not only from an artistic, but also from a technical point of view. Both body and glaze are of exceptional beauty. The exceedingly valuable results obtained by Muller, in spite of the scanty resources at his disposal, show clearly that he was a true ceramic genius, capable both of conceiving and of attaining high ideals.

Universally known, but perhaps not the most valuable of his creations, is the Flora Danica Service, originally intended for presentation to Empress Catherine II. Mention must also be made of the blue underglaze, mussel-painted, household porcelain, which has been constantly developed and increased for more than a century, and which is now an indispensable adjunct in nearly all Danish homes. Let me emphasize here, that, since the days of Muller, all Danish porcelain has been of the real, hard paste variety, both body and glaze being made from china clay, felspar and quartz and fired to very high temperatures, *e.g.*, cone 18. The Bornholm china clay, which was originally used, had soon to be abandoned, the colour of the ware not being satisfactory. Danish porcelain is at present made from Norwegian felspar and quartz, and from German or French china clay. It will therefore be seen that we have now attained to the production of ware, with a price so high in relation to the value of the raw materials employed, that we can ignore entirely the non-existence of suitable raw materials in our own country.

With Muller's retirement in 1801, the glorious days of the factory were ended, and for a very long time the standard continued to fall. Both from an artistic and an economic point of view, the results were unsatisfactory, and in the year 1867, the works were made over to A. Falck. In 1883, they were purchased by the above-mentioned "Aluminia" earthenware works, and the new manager, P. Schou, transferred the factory from the old premises

to Frederiksberg, where spacious buildings with many well-lighted workshops were provided. With regard to technical improvements, I may mention that Schou introduced an important alteration in the usual three-storied kilns for firing porcelain. This consisted in placing the fireboxes in the upper story, thus transferring the finishing chamber from the ground floor to the top. By this means the construction of the kiln was greatly simplified and firing became more uniform. On January 1st, 1885, Arnold Krogh was appointed art manager to the factory, and with him, as you know, began an exceedingly elaborate artistic development, which resulted in the modern renaissance of porcelain. It is not within my sphere to discuss the artistic side of this development, which depends in the first place upon an apt use of the very limited number of colours that can withstand the violent heat of the "grand feu." These include only cobalt-blue, gold, and, to a very limited extent, chromium. As a technical chemist, I may perhaps be permitted to mention the great invention of crystal glazes produced with zinc silicate, a process the application of which has spread all over the world, and which we owe to Clement, a former chemist at the Royal Factory.

Of quite another nature was the origin of our other important porcelain factory, that of Messrs. Bing & Grøndahl. Founded in 1853, by the young ceramist Grøndahl, of the Royal Factory, in association with the brothers M. H. and J. H. Bing, two highly respected merchants of Copenhagen, it has always been closely connected, since the death of Grøndahl a few years later, with the Bing family. For two generations, this family has supplied the gifted and energetic managers of the firm, even after its conversion, in 1895, into a limited company. The methodical and continuous development of the firm received a very decided impetus during the eventful year of 1888, when a large industrial exhibition was held at Copenhagen. A few years previously, the late talented director of the Museum for Applied Art, Pietro Krohn, became attached to the factory as art manager, and during his term of office, the artistic style of the Grøndahl porcelain underwent a radical change to modern decorative principles. At the above-mentioned exhibition, the firm exhibited the famous heron service, undoubtedly one of the most prominent creations in modern ceramic art. These two concerns—the three towers with a "B and G" in friendly rivalry with the three wavy lines—both of them artistically and technically on the same level, yet each with its own peculiar individuality, have created what is known in ceramic circles as the "Copenhagen style."

A highly important industrial development was initiated by Bing & Grøndahl in the manufacture of technical porcelain, particularly for electrical purposes. As early as 1857, the works had begun to make electric insulators for the telegraph service, and with the increasing importance of electricity, this department has

expanded so considerably that it is now a separate branch of the concern, and is known as the "Norden" factory, which now employs 400 people. It has already shown itself capable of dealing with the most difficult problems of this branch, as, for instance, the manufacture of insulators for a tension of 65,000 volts. These are also produced for export. Another concern the Dansk Porcellainsfabrik, of Kastrup, in Amager, also manufactures electro-technical porcelain.

The latest stage in the evolution of the Danish Ceramic industry is the production of artistic stoneware. Mainly under Japanese and French influence, a number of the younger ceramists conceived the idea of developing a Danish industry of *grès cérame*. Owing to the lower firing temperature—1,300°C.—, ornamental effects of great and peculiar beauty are possible, though they differ entirely from those obtained with porcelain. For more than ten years the two porcelain works have experimented on this problem, and the results can be seen at the factory showrooms. In this instance also, the mezozoic deposits of Bornholm have supplied valuable raw materials. The two firms engaged in producing artistic stoneware are P. Ibsens Enke, of Copenhagen, and L. Hjorth, of Rønne.

My attempt to deal with a very extensive subject has given my paper rather the character of a guide-book, an article which, at best, is apt to be more useful than enjoyable; but I trust the information I have supplied will be of some service to you.

IV.—A Visit to the Potteries of Norway, Sweden and Denmark.

By Dogar Singh.

ON arriving at Christiania, in August, 1920, I first proceeded to Skein. At Porsgrund, a small port, situated at a distance of ten miles from Skein, I visited a Pottery known as "The Porsgrund Pottery Factory." This factory was established in 1885, by the Norwegian Government, with a capital of one million Kroner, and the Government secured the services of two German pottery experts. When the factory passed the experimental stage and became self-supporting, it was transferred to a private limited concern, and the capital since then has been increased to approximately two to three million kroner.

The materials used for manufacturing the different kinds of articles are totally different from the English ones. In this factory, as a matter of fact, some new methods and processes for manufacturing pottery goods are applied. The body mixture does not contain bone ash and flint meal, which is commonly used in England, but consists mainly of felspar, quartz, and china clay. The machinery which is used for pugging the body materials for manufacturing hollow ware and flat ware is very economical and scientific. In the making of flat ware, the clay, as it comes from the pug mill, is given to the "batter out" who pulls off a piece sufficiently large to make the desired object. This clay is placed on a brass plate and flattened out by a special machine to the required size. The "batter out" then claps this sheet on the mould, when it is picked up by the under "jigger" man at his side, who places the mould on a revolving table. A lever is pulled which brings a knife-edged tool down on to the clay sheet, cutting away all surplus material, reducing the sheet on the mould to the same thickness throughout the piece, and forming the "under rib" on the bottom. The mould is then taken by the runner into the stove room to dry. One man and one boy can make fifteen hundred plates in a day. The stove room is also of quite a new type. Each room has twenty compartments and each compartment is divided into ten shelves, erected on a four-wheel waggon. When the goods are dried the whole compartment is pulled out and brought to the lift by which it is carried down to the first floor, whence it is taken to the bisque oven. It may be noted that all stoves for drying purposes are on the top floors and utilise the surplus heat given out by the kilns while cooling. Another process, a German

patent, is for engraving steel instead of copper plates, for printing purposes. The latter are nowadays very costly, and the designs are easily worn out on account of the softness of copper. The kiln used in this factory for porcelain and decorated underglaze ware is a circular one, and has a diameter of 2·5 metres and a height of 3 meters at the centre of the arch.

The biscuit oven constructed above, has the same diameter and a height of 2 metres. It has 10 fireplaces distributed in pits around the kiln. In firing, these pits are partially covered with iron plates, so as not to obstruct the passage around the kiln and the supply of fuel. The fireplaces are formed by flat grates about ½ metre wide and ¾ metre long, with deep ash pits. In the kiln there is, in front of the fire openings, a low ring-shaped bench of fire-brick which spreads the flame. The flame rises to the arch, then descends, and is drawn off at the bottom of the kiln by a central flue and 20 small flues, so arranged that the flame rises again in fire flues located in the wall of the kiln, between the fire places, and enters the second story of the kiln, which is used for the biscuit burning of porcelain or for green saggars. The latter are also fired at the top of the bungs in the lower part of the kiln.

On reaching Stockholm, I went to see the Gustafsberg Pottery, one of the proprietors and managing director of which is Mr. A. S. W. Odelberg. Mr. Odelberg's methods are too well known to members of the Ceramic Society to need further description from me. Moreover, an account is given of the works in the Proceedings (page xx.).

Another factory which was visited by me at Stockholm was the Rorstrand Works. The Rorstrand factory specialises in manufacturing porcelain for electric purposes. These insulating fixtures are made of a mixture of white-burning clays, felspar and flint. Articles like wiring fixtures, knobs, cleats, receptacles, attaching plugs, and switchboards are made by the "Dust press" method. The presses are very simple, each making from 1,500 to 3,000 pieces in a day, according to the size of the piece. The finished goods are sent to stove rooms, there they are dried and then carried to the dipping house to be dipped into the glaze, and finally placed in the saggars for firing. All these pieces are finished by one firing. Each piece is sent to the testing shop where it is electrically tested. Most of them are tested by a very high tension current of from 2,000 to 4,000 kilowatts. The above firm has also a very big collection of minerals and pottery goods from different countries, such as Japan, China, England, Germany, Italy, Austria, France, America, and a little from India, which they have collected from time to time by sending their men abroad, especially artists and designers, in order to copy new designs and shapes. The factory also makes hard paste porcelain which can compete successfully with bone china. As regards the colours and designs, they have excelled many foreign makes. They have

3,000 figures of animal and bird life and other fancy statues. In this line they have achieved a special success after a good many years of toil and labour.

From Stockholm, I went to Gothenburg. The pottery factory here is not so large and up-to-date as those I visited in Norway

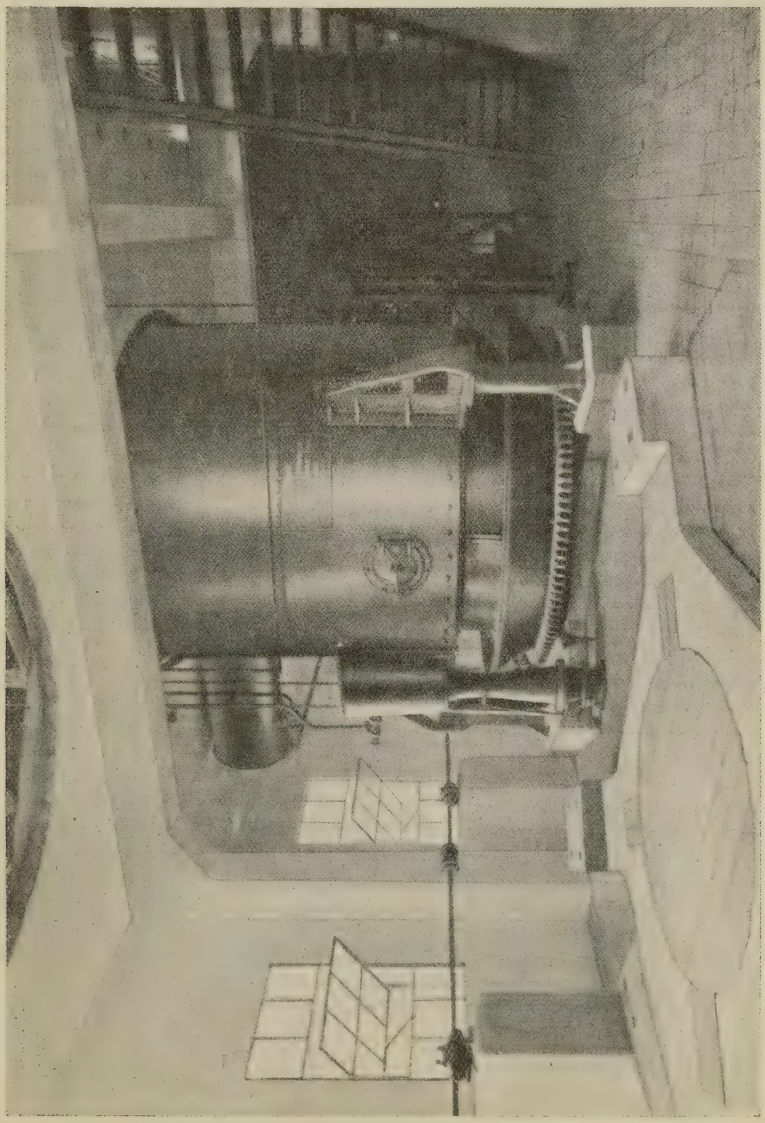
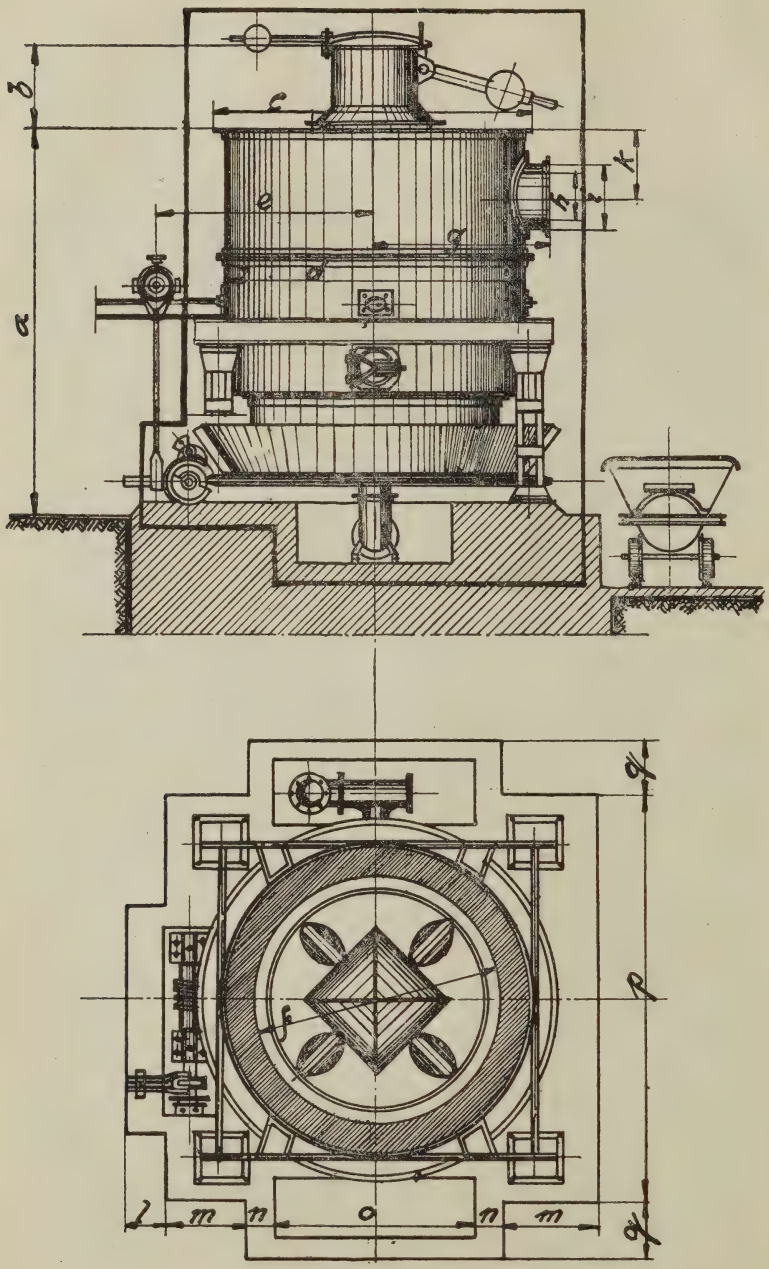


Fig. 1. Revolving-bottom Producer, Höganas.



Plan and Elevation of Producer.

and Stockholm. The produce of the factory is fairly good, but does not excel English ware. From here I proceeded to Höganas, where there is one of the largest concerns for refractory goods in Sweden. This factory also manufactures all sorts of acid jars and sanitary ware. The materials from which the silica bricks and slabs are made are quartz, sand, fireclay and quartzite. The capital of the firm is nearly 10 to 12 million Kroner. They have their own coal mines, but the coal is not of a good quality. The analysis of the coal they showed me, gave 50% ash, but the method which they have adopted for the utilisation of their fuel is quite an interesting one. No English firm uses such a bad coal. It is gasified in a producer, which is a German patent, and is called a "Revolving-bottom Producer." The bottom of the producer is always automatically revolving, so that clinker does not form on the grate. The gas is brought into a tunnel kiln, which is divided into eight chambers. While the goods are firing in the first chamber, the waste heat is utilised while passing through the under flues into the second chamber, and when the heating is nearly finished in the first chamber the second one is half fired. The doors of the first chamber are now opened, and the hot gases given off by the goods are utilised in the next chamber for combustion.

From Höganas I proceeded, via Malmö, to Copenhagen. Here I went to see the Bing & Gröndahl Porcelain Works. The firm of Bing & Gröndahl has only been in existence for about 50 years, and is thus a mere child among European porcelain works, but it has excelled many other factories in its products. The factory was established by Messrs. Bing & Gröndahl under the direction of a Dutchman, who died after being connected with this firm a few months. The factory is quite a modern one. A word must also be said about the endless profusion of skilfully modelled figures of animals, birds, and fishes. The pieces are either pure white, or delicately tinted in natural hues, with the same underglaze colours. The glazes are diversified by radiating crystals of zinc silicate, which have been copied from the Royal Copenhagen factory. The present art director is Mr. Willumsen, and the technical manager, Mr. Hallin. They have charming pieces of statues and crystalline glazes; almost all the figure work has been copied from the Royal Museum from the models of Thorwaldsen's works, the famous Danish sculptor. Here they are making experiments for firing their goods with liquid fuel. I asked whether liquid fuel would be cheaper for them than solid fuel. They informed me that now-a-days they could not get coal from England. They obtain their coal from America, and with regard to cost, there is no difference between liquid fuel and coal. They have converted their ordinary eight grate kiln by setting eight burners in their places. As they pointed out to me, the pieces coming from this kiln do not show any difference from pieces fired in ordinary kilns. They usually make hotel and ship wares, which are generally sold to Spain, France, England, and South America.

I also visited the Royal Copenhagen Factory, which has a special reputation in the Pottery world for its under-glaze colours. This factory, practically speaking, was established in 1869, but it was transferred subsequently to a private limited concern. A few years ago, the factory purchased a new plant for crushing and grinding the raw materials; this is worked by only two men. The quartz and felspar are first crushed in the jawmill, and are then taken out by a bucket conveyor to the crusher, where they are finally ground up to the fineness of rice. After passing through magnets the material is elevated, by a similar system, to the third storey, where it is screened through longitudinal sieves. Coarser grains are again brought down by gravity to the jawmill, and the finer stuff is stored in bins for use. According to the required weights, the materials are weighed and filled up through apertures in the floor which open just below into the ball mills, into which water is also fed from a tank. When the material is fine enough and sufficiently ground, china clay and other kinds of clays, according to the body mixture, are fed into the same cylinder in order to mix them uniformly. The cylinder then continues working for another

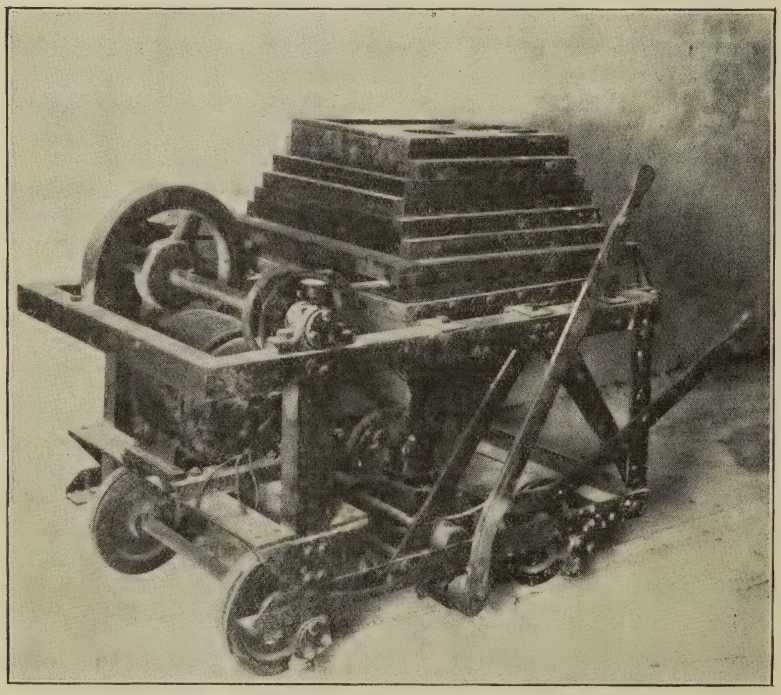
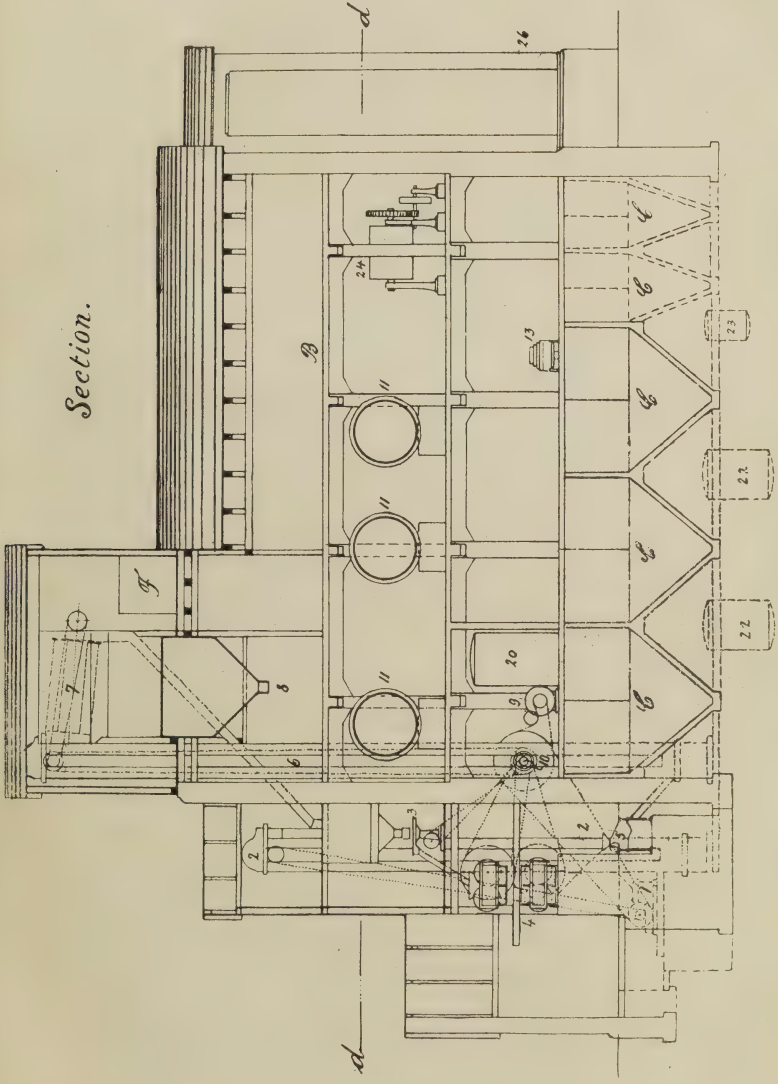


Fig. 3. Travelling Electric Sieves, Copenhagen.

hour. When it is ready, a flexible pipe is fixed to the mouth of the cylinder, and the slip is allowed to run through a pipe, from which it passes through a sieve, provided with 80, 100 and 110 meshes. When the cylinder has been emptied, the sieve travels by machinery to the next cylinder, so that only one set of sieves is used for the nine cylinders. This operation is done on the second floor. The



New Slip House, Copenhagen.

screened material is filled up into the agitator arks, where the slip is agitated by compressed air, and then it is allowed to settle for a few hours. The slip is afterwards run through the filter presses by the air compressor. The pressed material is stored in a cellar for nine to twelve months for souring, whence the material is brought down for pugging to the pug mill. This machine is of a special design. This factory has its own special colour-manufacturing branch, which is run by a skilled and trained man. By the use of pure Norwegian and Swedish felspar and quartz, and the finest English china clay, the most charming and attractive goods are manufactured, and on them life-like paintings of birds, fishes, animals and water or landscapes, or figure subjects are painted in elegant and admirable underglaze or enamel colours, such as cobalt-blue, peacock blue, pink, crimson, greys and greens.

Special attention has been given by the Danish factories to the manufacture of saggars. The raw materials are unloaded from the carts into the store rooms. These are provided with sloping floors, so that the materials are distributed automatically. Adjoining the clay bed is the drying room, fitted with kilns for drying clays. The roller mill, standing near the drying room, receives broken saggars to make grog. The dried clay is delivered directly from the drying rooms to the pug mills, while a bucket conveyor brings the ground grog forward into a horizontal set of sieves, where the grog is sieved according to the grain size. Two pug mills are erected for thoroughly pulverizing and mixing the clay and the grog together. One pug mill is vertical and one is horizontal. One stands so low that its hopper is level with the floor of the clay mill, and is situated below the vertical pug mill, and both are fitted so that the prepared body mixture is conducted from the one directly into the other. The mouth-piece in the horizontal pug-mill delivers the body mixture directly into the elavators. The material is then mixed with water, and allowed to stand for a few days. All the saggars are prepared by hand pressing. The technical engineer told me that their saggars last at least 30—40 firings. A piece of saggar material which I brought with me, was found, after gradation, to contain :—

17%	passing	No. 4	mesh.
13·5%	,,	6	,,
10%	,,	8	,,
10%	,,	12	,,
12%	,,	40	,,
8%	,,	80	,,
2%	,,	120	,,

Three different mixings of the saggar bodies are as follows :—

(1)	Fat clay from Halle	21·0
	Coarse sandy clay, Danish ..	19·5
	English ball clay	10·0
	Medium grog	33·0
	Coarse grog	22·0

(2)	Fat clay from Sweden ..	30·0
	English china clay	5·0
	Danish coarse sandy clay ..	20·0
	English Ball clay	5·0
	Medium grog	35·0
	Fine grog	10·0
	Coarse grog	15·0
(3)	Putchism clay	20·0
	Fat clay, Danish	10·0
	Coarse sandy clay, Danish ..	5·0
	Zettlitz china clay	5·0
	Fine grog	10·0
	Medium grog	30·0
	Coarse grog	15·0

Note—All the above figures are approximate.

On analysing the raw materials used, I obtained the following result :—

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Loss on Ignition
erstrand Felspar .. om Becker, Stetton	64·30	19·39	0·16	traces	0·32	12·95	2·30	0·75
wegian Felspar .. (Albite)	66·27	18·82	traces	0·50	0·16	1·54	11·67	1·40
tlitz Kaolin ..	46·75	39·10	0·76	traces	traces	0·30	0·70	12·00
wegian Quartz ..	98·52	1·04	—	—	—	—	—	0·20
glish C. Clay .. St. Austal) Fairie.	46·32	39·74	0·27	0·36	0·44	—	—	12·67

V.—The Refractory Materials of the London Basin.

By Henry Dewey.

BY the London Basin the geologist means that part of the south-east of England which is practically the same as the Thames Basin. It is bounded by two divergent ranges of hills, the Chilterns on the north and the North Downs on the south, and on the east by the coast. Both these ranges consist of chalk, but the dip of the chalk in the Chiltern Hills is generally towards the south, whereas in the North Downs it is towards the north. The chalk is covered between these hills by beds of sand, loam and clay, and occasionally with seams of pebbles which are known collectively as the Tertiary and Pleistocene Formations. Beneath these formations, however, the chalk is continuous with the two hill ranges. Originally it formed a nearly horizontal sheet over the whole district but by subsequent earth-movements it has been folded into a very shallow depression or "basin." This folding commenced before the Tertiary deposits were laid down in the sea and estuary, and was renewed after they had been deposited. The time, during which these operations continued, was of long duration and the episodes of deposition were separated by pauses when the land emerged above the water. Viewed broadly, however, there was a long-continued depression of the land beneath the sea which affected the eastern end of the basin more than the western. The sequence of deposits can be ascertained by observation of their occurrence at the surface, and by the examination of the material brought up from boreholes. By these means the thicknesses of the several divisions of the rocks have been computed. Exact measurement is impossible, but the following figures of some deep borings may be taken as accurate and representative of the thickness of the several stratigraphical divisions in different parts of the London Basin.

The chalk supplies very little material of a refractory nature. The bands of flint nodules, however, are used in some potteries, for instance the rounded black flint pebbles from the coast of Normandy are employed at the Coalport China Works near Bridgnorth.

	Ottershaw	Winkfield	Slough	Park Royal	Richmond	Streatham	Tottenham Court Road	Kentish Town	Mile End	Crossness
Alluvium	—	—	24½	—	10	10	22	—	20½	39
Upper Tertiaries	213	—	—	—	—	—	—	—	—	—
London Clay	336	136	—	263	160	153?	64	236	84½	—
Woolwich and Reading Beds	100	78	54	67	60	43½	51½	61½	41	47
Thanet Sands	—	—	—	29½	23½	35?	21	27	55	51
Chalk ..	646	725	757	624	671	623	655	645	654	696

Of the Tertiary Beds the Thanet Sands supply materials used in the manufacture of lime-sand bricks, and as casting and moulding sands. At Beddington near Croyden, Surrey, the white sand is mixed with lime, and after being moulded by machinery, the bricks are heated under steam pressure in autoclaves. The hardness of the brick is dependent upon the quantity of lime added and increases gradually up to the hardest brick which contains one-fifth lime. Lime, above 20 per cent., renders the bricks fragile. The following analysis of the sand appeared in The Brick and Pottery Trades Journal, May, 1908, Vol. 16, No. 5, New Series:

SiO_2	96·4
Al_2O_3	1·3
Fe_2O_3	0·7
Combined water ..	1·6

The foundry-sand which has been dug for many years in the neighbourhood of Erith consists of the more clayey bottom of the Thanet sand. It is an excellent moulding sand and its presence there in large quantities has been said to have determined the site of Woolwich Arsenal.*

Overlying the Thanet Sand in Kent and East Surrey, and lying directly upon the Chalk further west, is the series of glauconitic sands, variegated clays and shelly loams which comprise the Woolwich and Reading Beds. They have been worked at many localities for the manufacture of tiles, pipes and bricks, and the clay has been used for coarse pottery, for which it has been found suitable owing to its ductility. The sand, when white, is sometimes employed in glass-works.

The most remarkable deposit of this age is that which occurs at Epsom and Ewell, in Surrey. It consists of loamy sand of a greenish-grey to white tint and varies in thickness up to 5 feet.

* Whitaker, W., 'The Geology of the London Basin' (*Mem. Geol. Surv.* Vol. 4, part 1.) p. 390

In the time of Henry VIII. it was dug for moulding sand for goldsmiths' work and has been described by several of the old Topographers. In recent years refractory wares, used at many of the London and other gasworks, have been made from this material.

An analysis supplied by the company shows the following chemical composition:—

Silica	87·57
Alumina ..	3·60
Oxide of Iron ..	4·80
Lime	0·74
Magnesia	0·41
Potash	0·69
Soda	0·10
Water of Combination	2·09
	100·00

This analysis of NN Fire Earth, is supplied by Stone & Co., Ltd., Ewell, Surrey.

Unfortunately, this bed of loam is not known to occur elsewhere in the neighbourhood, so that its reserves are limited to a small area. Pipes and roofing tiles and red bricks are made from the plastic clay of the same pits and also from the neighbouring Cheam pits. Some of the Tudor bricks employed in building the now demolished Nonsuch Palace were made at the Ewell kilns, and about a century ago a special type of tile-brick was in demand for building houses to avoid the payment of a brick tax. Several old houses in Ewell still exist where these tile-bricks can be seen.

The plastic clay forms the most conspicuous characteristic of the Reading Beds between Reading and Croydon, but eastward of the latter town it appears to have passed into a shelly loam, useless for making bricks. At the Knowl Hill brickworks, near Reading, the mottled red and green clay was analysed by Messrs. Warren with the following result:—

Silica	50·00
Alumina ..	21·10
Lime	4·10
Magnesia	0·70
Potash, soda, phosphoric and sulphuric acids	12·80

Analyses of other beds at the same pit gave 59 and 78 per cent. of silica.*

A chemical examination of the plastic clay from Coldash Common, near Newbury, Berkshire, was made by Prof. Voelcker.‡

It is given below: a general analysis gave 54·64% of sand and 25·46 of pure clay.

* "The Geology of Windsor & Chertsey," (*Mem. Geol. Surv.*) 1915, p. 91.
‡ *Journ. Roy. Agric. Soc.*, **12**, 506, 1851.

Silica	.. ..	.. ..	73·736
Soluble oxides of iron and alumina	.. ..	5·031	
Insoluble	.. ..	.. 7·107	12·138
Lime	.. ..	..	2·980
Magnesia	.. ..	.. ..	0·047
Potash	.. ..	.. ..	2·077
Soda	.. ..	.. ..	0·525
Chlorine	.. ..	.. ..	a trace
Combined water and organic matter		..	8·698

The deposit overlying the mottled clays between Reading and Croydon is called the London Clay. Eastward of Croydon it is separated from the Reading Beds by a mass of pebbles and sand which attains a thickness of fifty feet at several localities. These pebble beds are called the Blackheath Beds but are of no value to the clay-worker. The London Clay is the principal deposit of Tertiary Age in the London Basin. It attains its maximum thickness of nearly 500 feet in the south-west of London, but thins out westwards until it disappears entirely in Berkshire where the overlying beds rest upon the underlying formations. Almost the entire thickness of the London Clay formation consists of a heavy clay of blue-grey colour, but where it has been exposed to the influences of rain and air it assumes a brown or red tinge by the oxidation of its iron compounds. It has been worked extensively for the manufacture of red bricks and Portland Cement, but more commonly in the neighbourhood of the outcrop of the overlying sands or underlying loams, both of which render it lighter and more plastic. At Bracknell, Berks, there are many large pits where the clays are dug and weathered. The following analyses were made for the Down Mill Co. of Bracknell clay, and for the Associated Portland Cement Manufacturers (1900) Ltd., of clay at Swanscombe, Kent.

Analysis of Red Clay (London Clay) from Down Mill Pit, Bracknell, Berks.

		Blue Clay (same locality)
SiO_2	73·4	71·0
Fe_2O_3	6·35	3·7
Al_2O_3	5·95	10·8
CaO	13·80	9·8
Combined water, etc.	·50	5·7
	100·00	100·00*

* This analysis is of the clay dried at 100° until the weight was constant: the moisture which was driven off amounted to 3·88%

Analyses supplied by the Down Mill Brick Co. Ltd., Bracknell, Berks., and made by C. D. Cooper, Oxford Road, Reading, Berks.

Analyses of London Clay from Swanscombe Wood, Kent:

Silica	30·84	28·74
Alumina	13·72	14·91
Ferric oxide ..	6·30	5·81
Lime	1·06	1·08
Magnesia	2·80	2·59
Sulphuric anhydride ..	0·49	0·67
Loss on ignition	6·88	5·86
Insoluble residue ..	36·52	39·26
The insoluble matter consists of:—		
Quartz	22·02	22·70
Silica }	9·88	11·22
Alumina } Felspar ..	2·80	3·18
Soda } ..	1·70	1·93
TiO_2	0·12	0·23

Analyses by the Associated Portland Cement Manufacturers (1900) Ltd.

In Surrey and Kent the London Clay gradually changes into a series of alternating seams of fine sands and loams, which have been termed the "Claygate Beds" after the locality where they are typically exposed and developed. These beds afford excellent material for the manufacture of bricks, and there are many pits dug in them at Claygate, Chessington and Tolworth. Westward of Weybridge the Claygate Beds had been removed by denudation previously to the deposition of the next group of sands and pipe-clays. These are termed the Bagshot Sands. In the London Basin they are not employed as brick-earth but are occasionally dug to mix with the heavier clays. In the Hampshire Basin, however, they have long supplied pipe and pot clays.

Overlying the Bagshot Sands is another group of loams and glauconitic sands which resemble in their lithological characters the Woolwich and Reading Beds. They are exposed principally in the Sunningdale, Ascot and Crowthorne districts and there are made into bricks of special character. Near Ascot a large pit affords the material used in the manufacture of Lawrence's Rubber Bricks. These beds pass upwards into yellow sands known as the Barton Beds which are of no use for refractory wares.

In the London Basin there ensued a prolonged period of erosion after the Barton Beds were laid down, and many formations, represented in the Isle of Wight and the opposite shores of Hampshire, Sussex and Dorset, are unknown. During this period atmospheric weathering acted on the chalk and dissolved out the carbonate of lime, leaving only a brown or black clay. This clay has been mixed, by natural agencies, with remnants of the Tertiary clays, and the resulting formations have been grouped under a general term of Clay-with-flints. This material has been dug at many localities on the North Downs and the Chiltern Hills, for brick making. Later than these formations are a series of

brick earths of alluvial origin lying upon gravels which also owe their existence to the Thames. These form flats or terraces flanking the river and lying at several stages above the present level of its waters. The principal brick-earths form wide-spread tracts at about 90 feet and 50 feet, respectively, above sea-level. Most of the large brick fields, which formerly supplied London with its building bricks, were in the alluvial brick-earths. Without giving exhaustive lists the following may be cited as representative. Those near Slough, Langley and Dawley, Shepherds Bush, Acton, Southall and Hayes. In Fulham and Chelsea also bricks were formerly made, while great thicknesses of brick-earth are still worked at Crayford and Erith. In North London there were extensive brick yards at Clapton, Stoke Newington and Highbury, also at Edmonton and Enfield.

Several of the formations supply sand which is used in the manufacture of glass, but this subject has already been fully dealt with by Professor P. G. H. Boswell* and so is omitted from the above account of refractory materials.

* "British Resources of Sands and Rocks used in Glass-making."—2nd Ed., 1918.

VI.—The Gypsum Industry.

By A. Brittain, M.Sc., A.I.C & C. Elliott, B.Sc., A.M.I.C.E.

THIS paper is intended to be not so much a dissertation on the chemical properties of gypsum and the phenomena which occur during its dehydration and its subsequent rehydration, as a consideration of the general methods employed for the conversion of the mineral into its manufactured products, and the application and testing of these products.

Gypsum is a hydrated sulphate of lime, and when pure is made up of one molecule of calcium sulphate combined with two molecules of water, so that the composition is:—

Lime	32·6%	=	Calcium sulphate	79·1%
Sulphur trioxide	46·5%			
			Water ..	20·9%
				100·0%

Gypsum deposits are, however, never absolutely pure, but contain varying amounts of impurities such as sand, clay, calcium and magnesium carbonates, magnesium sulphate, oxides of iron and sometimes sodium and potassium salts.

Gypsum is widely distributed throughout the world and important deposits are found in England, Germany, France, Switzerland, the north American continent and Australia.

Deposits in Great Britain. In Great Britain gypsum is found in many districts, but the most important deposits occur in Cumberland, Derbyshire, Nottinghamshire, Staffordshire and Westmoreland. They are usually associated with shales and marls. The seams vary widely in thickness, the thickest being found in the northern counties. Thus at Cocklakes Mines, Cumwhinton, Cumberland, the thickness is said to reach 28 feet at a depth of 60 to 140 feet, and the deposit extends over an area of 40–50 acres, while at the Knorhill Mine, Cotehill, it is 15–18 feet thick.

Full particulars of the British deposits can be found by referring to the Memoirs of the Geological Survey, Vol. iii., Gypsum and Anhydrite.

Varieties of Gypsum. Gypsum is found in several clearly defined forms, which are classified thus:—

(1). Crystalline gypsum, usually called selenite, which is generally almost colourless and transparent or translucent.

(2). Fibrous gypsum, usually called satinspar.

(3). Rock gypsum or massive gypsum is the form in which the mineral is mostly found in large deposits. When it is found as a fine-grained and translucent variety, it is called alabaster and is cut and ground to various shapes for ornamental purposes.

(4). Seed or sand gypsum is composed of small crystals of gypsum.

(5). Gypsite or gypsum earth is composed of very fine particles of gypsum, this variety being generally found overlying seed gypsum deposits.

The last two varieties, seed gypsum and gypsite, are not found in this country.

Gypsum is usually found associated with natural anhydrite which is anhydrous calcium sulphate. It is valueless for the manufacture of plaster and probably its only real use is as metal for roads, and that only to a small extent.

Procuring Gypsum. Whether gypsum has to be mined or quarried depends almost entirely on the location of the deposit. If the overburden is soft, easily removed and of no great depth, it is entirely stripped and the underlying gypsum quarried, but if this is not the case, then recourse must be made to mining. In this country the greater part of the mineral is mined.

In some cases gypsite deposits are found. The earthy gypsum is a surface deposit and has only to be loosened by horse ploughs, scrapers, or other simple means. Unfortunately, most of the deposits are small and soon exhausted, but the conversion into plaster is very much simpler than in the case of the solid varieties. An interesting letter was received from the Overland Cement Plaster Co., of Laramie, Wyoming, who work a gypsite deposit. An extract from this letter reads: "Our gypsite occurs in beds that are sometimes as thick as 16 or 18 feet. The top soil is covered with grass. We strip off the top 6 or 12 inches. We then loosen the gypsite with an ordinary farm plough or farm disc harrow and load it on cars with wheeled scrapers. We haul the gypsite to our mill and store it in a large shed. We do not grind our raw material in any part of our process as it is fine enough without grinding."

Uses of Gypsum. Gypsum, after crushing and grinding, has many uses, of which the most important are as follows:—

In the *manufacture of Portland cement,* it is used as an agent for retardation of the setting, the actual amount added being of the order of 1–3 per cent., depending on the set desired and limited by the specifications adopted as standard by various countries. In the paint trade it is used as a substitute for white lead or for barytes; in the paper trade as a filler, being substituted for kaolin; in the cotton and lace trades to give a finish to cheap classes of goods; to some extent in the tinplate trade for polishing tin plates; in agriculture, as a method of supplying sulphates to the soil, and, although in this country this use is not so general as abroad, a fair amount is used in the Kent and Sussex hopfields. In the chemical manure trade, gypsum is added to superphosphates to reduce the phosphate content to about 80 per cent. It is used to a limited extent in optical apparatus and in making preparations for examinations by

polarised light.

In breweries gypsum is added to the water in order to give it the permanent hardness which is found desirable. At Newark and Burton-on-Trent and other places such water is found, but in parts of the country where the water is not of this nature, it is usual to add gypsum, which must be free from marl. Gypsum as alabaster, such as is found in Staffordshire and Derbyshire is used for inside decorative work, and many beautiful examples of its use are to be found. The alabaster reredos, by Gilbert Scott, in Ely Cathedral is an excellent example, and it can be seen as ornamental work in Manchester, Buxton and other places. Probably its best known use is for electric light shades.

We understand that gypsum is used in the Badische Synthetic Ammonia plant to convert the ammonia into ammonium sulphate according to the equation:—

$$2NH_3+CO_2+H_2O+CaSO_4\cdot=(NH_4)_2SO_4+CaCO_3.$$

But by far the most important use of gypsum is the manufacture of what is commonly known as Plaster of Paris, and this brings us to the main part of this paper.

The Dehydration of Gypsum. Before considering the technical treatment of gypsum for the production of plaster, a brief survey of the literature concerning the dehydration of gypsum will be an advantage. Calcium sulphate, both in combination with water and in the anhydrous state, can exist in various forms.

A. In combination with two molecules of water, Davis[1] has shown that two crystalline forms can exist:

(1). Monosymmetric form (Gypsum).

(2). Orthorhombic or labile form of the dihydrate.

When gypsum is heated a period of induction takes place, during which no water is given off and which, according to Davis, is due to the conversion of the monosymmetric form into the orthorhombic form.

B. As the hemihydrate, $CaSO_4,\frac{1}{2}H_2O$ (orthorhombic) which sets rapidly with water.

C. Without water as soluble anhydrite (orthorhombic), a form which is very hygroscopic and which sets rapidly with water.

D. Without water as slow-setting Anhydrite (orthorhombic), which only takes water up and sets slowly.

E. Without water as natural anhydrite (orthorhombic), usually regarded as non-setting although Keane[2] claims that this form will set with water if sufficiently finely ground.

The earliest worker on the problem was Lavoisier[3], who, in 1765 and 1766, concluded:—

(1). That Gypsum is a salt formed by the union of "acid of vitrol" with earth of lime, containing water of crystallisation

[1] *J. Soc. Chem. Ind.*, **26**, 731, 1907.
[2] *J. Phys. Chem.*, **20**, 1916.
[3] *Comptes rend.*, Feb. 27, 1765, and Mar. 16, 1766.

which can be driven off by gentle heat, the product being Plaster of Paris.

(2). That overheated plaster will not set with water.

(3). That the setting of plaster of Paris is a simple crystallisation. Gypsum deprived of water by fire, re-absorbs it readily and again becomes crystalline.

This latter conclusion of Lavoisier, that the setting of plaster is a simple crystallisation, was endorsed by Le Châtelier in 1887, who also gave the now generally accepted explanation of the nature of this setting, a matter which will be discussed later. From data obtained by heating gypsum at a steadily increasing temperature, Le Châtelier concluded :—

(1). That the dehydration of gypsum is incomplete at 155°C., but complete at 194°C.

(2). That gypsum when heated, loses water in two stages, the temperature of these two stages being 128°C. and 163°C. At the end of the first stage the product has a composition corresponding to the formula, $CaSO_4,\frac{1}{2}H_2O$.

From a study of vapour pressures, E. F. Armstrong (Dissertation, Berlin, 1901), found that the inversion point of gypsum into hemihydrate was 107°C., while Van't Hoff and his co-workers postulated (also from vapour pressure determinations), that the transformation temperature of gypsum into soluble anhydrite is lower (viz., 93°C.) than the temperature of transformation of gypsum into half hydrate (107°C). If this were so, it must be concluded that when gypsum is heated at a temperature below 107°C. in an open vessel exposed to the air, soluble anhydrite would be formed directly, without the formation of the half hydrate as an intermediate product. Davis[4] pointed out that Van't Hoff's results were open to serious criticism, and re-established—

(1). That gypsum heated in an open vessel at 98°C. lost water with the formation of the hemihydrate, further prolonged heating at this temp. having no effect.

(2). That the hemihydrate only changed to soluble anhydrite at 107°C. or above.

(3). That soluble anhydrite, on rehydration by absorption of water from the air, formed the hemihydrate.

From his results he concluded that, contrary to Van't Hoff's opinion :

(1). The half hydrate is formed as the intermediate product in the dehydration of Gypsum.

(2). The transition temperature of the system gypsum-hemihydrate is 98°C.

(3). The transition point of the system hemihydrate-soluble anhydrite is 107°C.

These conclusions are important, since the existence of the

[4] *J. Soc. Chem. Ind.*, **26**, 727, 1907.

hemihydrate had previously been challenged by Cloez[5] and the hemihydrate is the main constituent of all commercial plasters. In actual technical practice for the dehydration of Gypsum to form what is generally termed Plaster of Paris, temperatures far exceeding 98°C. are employed.

Hursh[6] states that gypsum, when heated above 200°C. for some time, becomes completely dehydrated and requires a considerable time for its rehydration. The setting properties are not, however, seriously affected if the heating is even in excess of this temperature, provided that the time factor is not great.

Eckel[7] states that no anhydrous calcium sulphate is formed under technical conditions until the temperature is as high as 204°C., and he fixes the limiting temperature for the manufacture of plasters at 175-200°C.

Winterbottom[8] remarks that this is only partly true since he has found varying percentages of anhydrous calcium sulphate or slow-setting anhydrite in all commercial plasters.

L. A. Keane[9], after a consideration of all the previous literature, writes in this connection as follows:

"It seems that American practice is to burn at 175-200°C. because the complete dehydration only takes place above 200°C., whereas the Germans burn at 130°C. in order to prevent the formation of the anhydrous form above this temperature. The English burn apparently at 110-120°C., although admitting that the temperature can be raised to about 200°C. before the anhydrous form can be produced." "Bancroft pointed out that these statements could be reconciled if the time factor is taken into account. If we assume that gypsum loses water slowly at 110°C. and more rapidly at 200°C., plaster can be got at 110°C. given time enough, whereas less time and a temperature of 200°C. gives the same end point.

All these statements are too general and only partly correct, for we have found that the temperature at which Gypsum is technically dehydrated depends on the particular method employed and on the size of the particles. There is, however, a wide range of temperature over which gypsum can be dehydrated to obtain

(1). The hemihydrate.
(2). Soluble anhydrite.

That this is so arises from the fact that gypsum only develops its true vapour pressure very slowly and the rate at which this pressure is developed decreases with increase in the size of particle.

Van't Hoff[10] gives the dissociation pressure of gypsum as 564·8 mm. at 95°C. and 710 mm. at 100°C.

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[5] *Bull. Soc. Chim.*, **29**, 169 & 171, 1903.
[6] *Trans. Amer. Cer. Soc.*, **17**, 549, 1915.
[7] *Cement, Lime and Plaster*, 1905, p. 75.
[8] *Bull.*, **7**, *Dept. Chem.*, South Australia.
[9] *J. Phys. Chem.*, **20**, 704, 1916.
[10] *Zeit. Phys. Chem.*, **45**, 267, 1903.

Precht and Kraut[11], working at 100°C., allowed the hydrated salt to dissociate into an evacuated tube, and their results are interesting as they show that 1,000 mg. of gypsum had not reached equilibrium after 14 hours heating at 100°C.

Some of their results are given in the following table :—

Gypsum, Mg.	Time Hrs.	Vapour Pres. Mg. of Hg.	Vol. Vapour Ccs.	Water loss %
534·7	10	417·2	153·8	9·14
776·5	10	474·0	164·4	8·66
921·3	11	570·2	170·9	7·29
1000·0	14	519·1	172·2	6·94

They also found that a piece of gypsum, 0·85 gms. in weight, gave a pressure of 57·1 mm. after heating for 8 hours, whereas the same weight of powdered material reached a pressure of 400 mm. when heated at the same temperature. These facts being established, it is obvious that gypsum can be readily superheated far above its transition point without the theoretical changes taking place.

In heating finely-ground gypsum with a steady rise in temperature, Le Châtelier observed an inversion point at 128°, and another at 163°. The result is of special interest, in so far as it indicates the course of dehydration of ground material in actual practice. The actual temperatures of the inversion points in Le Châtelier's experiments are of no especial interest since it will be shown that these can be made to vary, between limits, according to the conditions of the experiment. Winterbottom, in a set of experiments in which finely-ground gypsum was heated by a bath maintained at constant temperature, obtained a series of time-temperature curves, which are, however, somewhat vague, owing to the fact that the continuity of heating was broken in order to weigh the product.

We have carried out a series of experiments in which finely-ground gypsum (80 to 85% through 100 mesh) was heated in a glass beaker 8·25 cm. diameter, the depth of the fine material being about 5 cm. The mass was heated with constant agitation in an oil bath, maintained at a constant temperature throughout the experiment, while the temperature of the material was noted at frequent intervals. Experiments were conducted at bath temperatures ranging from 130 to 230° and in every case a time-temperature curve was obtained similar to that of Le Châtelier. It was found that under these conditions the inversion points of the system gypsum-hemihydrate and hemihydrate-soluble anhydrite rose with the temperature of the bath, and it would appear from our experiments that there is a relationship between the temperature

[11] *Liebigs Ann.*, **178**, 138, 1875.

of the heating medium for finely-ground gypsum and the temperatures at which the changes, gypsum to hemihydrate and hemihydrate to soluble anhydrite, take place. Thus, with the bath at 130°, the change gypsum to hemihydrate took place at 109°, while with a bath temperature of 230°, the same change took place at 132°, the transformation taking place more quickly at the higher temperature.

This change, therefore, takes place at a temperature within the limits of this temperature zone, depending upon the conditions under which the gypsum is heated, but this temperature remains constant until the hemihydrate stage is practically complete.

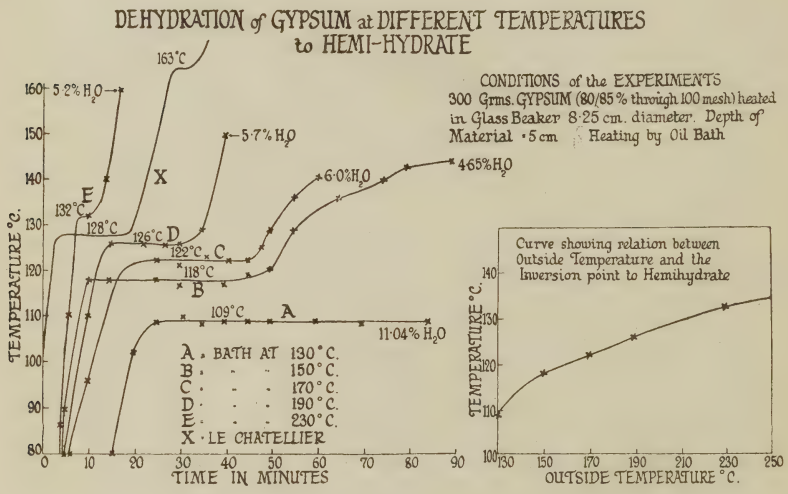


Fig. 1.

A similar temperature zone exists for the change hemihydrate to soluble anhydrite, the limits of which, in technical practice, appear to be approximately 160° to 200°. Below 160°, the change takes place slowly, no "boiling" occurs and agitation is consequently difficult.

Under the same experimental conditions *coarser gypsum* (passing 40, caught by 80 mesh), gave similar time-temperature curves, but the actual time for dehydration was longer, and at the end of each break in the curve, the product contained more water, *i.e.*, more unchanged material, than in the corresponding experiments with the finer material. Also owing to the larger size of particle and the slow rate of dehydration no "Boiling," *i.e.*, no agitation of the particles by the escaping steam, took place as was the case with the finer material.

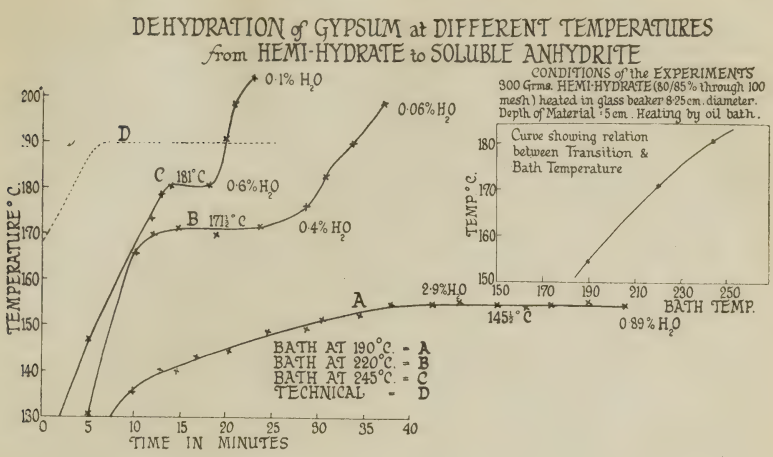


Fig. 2.

In the dehydration of *lump gypsum* at relatively high temperatures, the two most important factors to be considered are:—

(1). The low themal conductivity of calcium sulphate.

(2). The absorption of heat during the dehydration of the crystals.

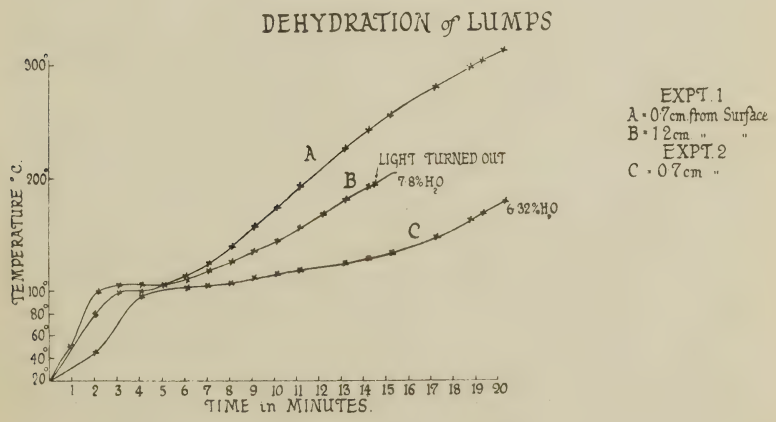


Fig. 3.

Both these factors combine to cause a very steep temperature gradient from the surface to the centre of the material. In consequence of this, it is possible to have anhydrous calcium sulphate at a dull red heat at the surface of a lump, and, at the same time, a few mm. from the surface, for either hemihydrate or unchanged

gypsum to exist. This was demonstrated in the following manner. A cylindrical lump of gypsum, 80 mm. diameter and 40 mm. high, was drilled horizontally to the centre with two holes so that the thickness of the gypsum from the surface was 7 mm. and 12 mm. respectively. A thermometer was placed in each hole and tightly packed with powdered gypsum. The lump was then placed on an iron plate heated to redness (about 600-700°) and the rise of temperature noted.

In both cases, a definite break in the curve was observed in the neighbourhood of 100°, due to the formation of hemihydrate. At the end of 20 minutes the heated surface was red hot (probably about 600°) and consisted of anhydrous calcium sulphate. At a distance of 12 mm. below the surface at the end of the same period, the material consisted mainly of hemihydrate with 6·3% water, at a temperature of 173°, whilst 7mm. from the heated surface, the temperature was 190 after 15 minutes; the material contained 7·8% water and was, therefore, also mainly hemihydrate. Apart from emphasising the low themal conductivity, the experiment makes it clear that dehydration takes place inside the lump at temperatures far below the surface temperature, and that even under these conditions, the hemihydrate was formed considerably below 200°.

We can now state that under technical conditions :—

(1). In the dehydration of lump gypsum by hot gases, the hemihydrate is formed at a much lower temperature than that existing at the surface, there being an inversion point in the neighbourhood of 100°.

(2). In the calcination of finely-ground gypsum, the production of hemihydrate occurs within the approximate temperature limits of 109° to 130°.

(3). The hemihydrate-soluble anhydrite change occurs within the approx. temperature zone of 160-200°, the product being practically anhydrous, before the further rise in temperature occurs. We will now proceed to examine these results in the light of technical practice.

Description of various processes for the dehydration of gypsum. When the gypsum rock is delivered from the mine or quarry, it may be necessary to remove any adhering impurities such as clay, and to grade the material according to its colour. This is universally done by hand. The whitest and cleanest variety is used for the manufacture of plaster while the discoloured and probably impurer part is sold, after grinding, for various purposes, although even the impurer varieties are also made into a low grade plaster. In some few cases the gypsum is washed, such a plant being described by Winterbottom (Gypsum and Plaster of Paris, *Bulletin* No. 7, Department of Chemistry, South Australia). It is proposed to describe the various processes employed for the dehydration of gypsum more or less in detail as far as our present information goes. The best known methods are the kiln method, the open-

pan process, the kettle process and the continuous rotary calciner.

The Kettle System. The kettle process is purely of American origin and development and is almost exclusively used in the United States and Canada. Although plants using the process may differ slightly and the details of the kettles themselves may vary somewhat, the process can be regarded as, more or less, standardised. The gypsum rock after grading by hand, if this is necessary, is ground in several stages to a fairly fine powder before calcination. The rock is first crushed in stout rockbreakers or nippers, to about 2″ cube and then in rotary crushers to about $\frac{1}{4}$″ cubes. If the gypsum contains much hygroscopic moisture it is usually dried before further grinding, this drying being effected in the well-known rotary cylindrical machines, which are extensively used in many other industries. It is usual to employ coke to effect the drying as, otherwise with coal, there is a danger of colouring the gypsum.

After drying, the gypsum is ground to a fine flour, about 60 or 80 mesh, in pulverisers of various types such as Buhrstone mills, either vertical or horizontal, emery mills or disintegrators. Buhrstone mills consist of two siliceous stones, with radiating grooves cut in their grinding surfaces. One of these stones is stationary, while the other revolves concentrically against it. The output of a vertical mill is greater than that of a horizontal, but the ground material is not so uniform. As the stones of Buhr mills wear rapidly at the outer edges, so that it is necessary to regrind every fortnight approximately, emery wheels are very frequently used instead. These emery wheels have buhrstone centres but these are surrounded by concentric rings of grooved emery blocks, and slabs of sandstone or other soft stone, the whole being kept in place by an outer iron band. It is easy to redress the softer stone so that the length of time that a particular mill is in operation is considerably increased. Disintegrators consist essentially of several revolving cages of iron bars running concentrically inside each other. These cages run in opposite directions and when the gypsum is delivered at the centre, it is rapidly disintegrated. From the disintegrators the finely-ground gypsum is elevated to overhead storage bins, whence it is run into the kettle as desired.

These kettles vary in size from 4 feet to 14 feet diam., and from 4 feet to 8 feet deep, while their capacity is anything from 2 to 24 tons of gypsum. The sides are made of boiler quality plates, varying in thickness from $\frac{1}{4}$ inch for the smaller, to $\frac{7}{16}$ inch for the larger vessels. The bottoms, usually about $\frac{5}{8}$-inch thick, are made of high-grade, well-annealed cast iron or semi-steel, a metal with a low coefficient of expansion being very desirable. Sometimes pressed steel is used in this connection. They are made either in one piece or in sections, but any advantage gained by the use of sections is more than counterbalanced by the difficulty of fitting new sections to old ones which have become distorted by the continuous heating. The firegrate is placed 6 to 7 feet below the

bottom of the kettle and the hot gases circulate round the pot and through horizontal flues of 14 inch diameter, extending through the body. A stirrer is provided to keep the mass well agitated and the kettles are completed with an outlet for the calcined material. A cover is provided with an inlet for the raw gypsum, an outlet for steam and dust and a manhole for inspection. The H.P. required to drive the stirrer varies according to the size from 4 H.P. in the smallest to 50 H.P. in the largest. Thus a kettle, 8 feet diameter by 8 feet deep which would calcine 6 to 7 tons in one charge, requires about 15 H.P., while a kettle 10 feet diameter by 8 feet deep would treat 12 to 14 tons and need about 25 H.P.

As soon as the calcination is completed, the hot material is run out into a cooling pit. Immediately a previous and completed charge has been run off from the kettle, the recharging with raw gypsum is commenced. The time for charging varies considerably. When gypsum gives up its water of crystallisation, the ascending steam keeps the whole mass in an agitated condition and it flows almost like water, having every appearance of boiling. During charging the stirrer is continually rotating, and it is usual to relieve the strain on the gearing by only running in the gypsum at such a rate that the increasing volume of material in the kettle is always boiling, and, therefore, fluid, the temperature being about 110°. The actual time of filling depends on the fineness of the ground gypsum, on the amount of free moisture in the material, and on the weight of the charge. To charge 14 tons requires from half an hour to an hour and a half, or even longer if the gypsum is coarse and wet, but with previously dried and fine material, and good firing the material can be fed in at a rapid rate and yet maintained constantly on the boil. When the charging is completed, the temperature rises to a point which, as has been shown, depends on the rate of heating.

The temperature after completion of the charge rises to, and is maintained at, about 245°F. (118·5°) until the main portion of the gypsum is converted into hemihydrate. At the end of this change the temperature rises rapidly, this rise being sometimes preceded by a slight fall of 5 to 10°F. The exact reason for this fall is not quite clear, but we offer a possible explanation. At the end of the hemihydrate stage or first boil, agitation by the escaping steam ceases. The less efficient agitation due to this cause results in a temperature lag, the heat being transferred at a slower rate to the centre of the material, so that for a few minutes the temperature actually drops.

The extent of this drop might depend to some degree on the design of the kettle, but in a good design of kettle this would not occur and the temperature increase should approximate to a straight line. At about 300°F. (149°C.), boiling practically ceases and the charge could be run off at this temperature, and this is actually done by some manufacturers. At this point the amount of water in the

plaster is usually 5% to 6%. When the heating is continued beyond this point, the whole mass settles down in the pot by about 12 to 16% of its volume, this occurring at about 325°F.(163°C.) The charge is now no longer fluid and is correspondingly difficult to agitate.

At the temperature of about 375°F. (190·5°C.), the charge rises up again in the kettle, boiling recommences much more vigorously than before, and the material is now quite fluid again. The temperature remains steady until practically all the water is driven off, but the charge must be run off before the boiling ceases, as otherwise the mass would again sink down in the pot and could not be run out.

First Settle Plaster. When the plaster is run off between the end of the first steady point and the beginning of the second, it is known as first settle plaster, and consists mainly of hemihydrate with small amounts of unconverted gypsum and soluble anhydrite, the proportions of these depending, to a great extent, on the temperature at which the plaster is discharged.

Second Settle Plaster. When the calcined material is run off at the end of the second steady, it is termed second settle plaster and consists mainly of soluble anhydrite with varying amounts of the hemihydrate and slow-setting anhydrite. Second settle plaster has a setting time of about ½ to 1 minute, but unless it is put into air-tight receivers while still hot, it rapidly picks up moisture and reverts to the hemihydrate. Unless it can be used immediately, there is little advantage in carrying the calcination to the soluble anhydrite stage, although the plaster obtained from soluble anhydrite which has been exposed to the air is undoubtedly better than hemihydrate obtained by stopping at the first stage of the calcination.

In this connection we have received information from American Manufacturers concerning the temperatures reached during calcination. The Dakolia Plaster Co., Rapid City, South Dakota, carry their calcination to an end point of 315°F. (157°C.) when calcining for ordinary plaster.

Messrs. Calvin Tomkins, whose offices are at 33, Church Street, New York, run off at 200°F.-320°F. (149-160°C.), while the Overland Cement Co. at Laramie, Wyoming, run off at 350°F. (176°C.); the Higginson Manufacturing Co., Newburgh, N.Y, and two other firms near Laramie, Wyoming, carry their calcination to the soluble anhydrite stage and discharge their kettles at a final temp. of 385°F. (196°C.)

Time for Calcination. The actual time occupied to calcine the material from completion of the filling to the point where it is run off depends on the rate of heating, and on the size of the charge. In some cases, with forced draft and smooth conditions of working, the time required for obtaining first settle plaster can be reduced to less than two hours, including filling and emptying.

Messrs. The Manitoba Gypsum Co., dry their gypsum at about

150°, and not only do they remove hygroscopic moisture, but also part of the combined as well, so that the total run in the kettle is only 1½ hours, but most plants appear to take 2½ to 3 hrs. for calcination.

When the calcined material in the hot pit is cool, it is emptied by an Archimedean screw and elevated to bins whence it passes to screens of various types such as of the bolting or shaking kind. The plaster passing the screens is bagged, while the oversize is ground in small buhr mills. If the plaster is intended for wall plaster, which requires a slow set, it is passed to mixers where retarders and hair are mixed with it.

The English System. The English method of manufacturing plaster differs radically from the American in that, whereas in the kettle system large charges are calcined at a rapid rate, in the English system, small charges are treated at a slow rate. The preliminary drying of the gypsum to remove hygroscopic moisture, which is almost invariably associated with American practice, is not generally found in this country. The raw material is crushed in jaw breakers, ground in buhrstone mills, and then run direct into the pans.

These pans are large, shallow, circular vessels with flat bottoms and vary in diameter from 18 to 22 feet. The bottoms are made of cast iron plates 2″ thick with a 4½″ firebrick lining underneath, while in some of the older works, these plates are not used, but firebrick tiles, bedded on the brickwork forming the flues, make the surface on which the calcination is effected. It is obvious that the temperature of the floor or bottom of the pan must vary considerably, since there is such a very large surface and uneven boiling can actually be observed. The stirring of the mass is effected by heavy chains dragging along the bottom of the pans. The chains are suspended from two arms which slowly revolve, these arms being driven by suitable gearing. The charge is usually about 3 to 4 tons for the largest size pans and when spread out in the pans, the depth of the material is about 6″, this spreading being done by the chains as they revolve. Owing to the brick lining, the heating is obviously slow as well as uneven, and since both the hygroscopic and chemically combined water have to be removed, the time needed for calcination is considerable, usually 3 to 4 hrs. While the water is being driven off, the material has the appearance of boiling and flows very freely, so that agitation is easily effected, but when the main bulk of the mass has been converted to hemihydrate, it becomes heavy and runs before the chains, whereby the workmen judge that the desired point has been reached, and that the pan can be discharged. The temperature throughout the calcination varies between 110°C. and 120°C., according to the rate of heating in any particular case, and the resulting product is mainly hemihydrate, together with varying amounts of unconverted gypsum and soluble anhydrite, the water-content being between 5 and 6%.

There is no sudden temperature rise at the end of the hemihydrate stage such as is associated with American practice and no attempt is made to carry the calcination to the soluble anhydrite stage, since under the circumstances, this would take considerable time without any corresponding commercial advantage.

After calcination, the treatment of the plaster varies according to the use for which it is intended, the general lines of treatment being similar to those as described under American practice.

Rotary Calciners. Rotary calciners for the dehydration of gypsum are all based on the same principle, although differing in detail. They consist of long, rotating, cylindrical shells of steel, through which the gypsum and hot furnace gases pass in opposite directions. The shells are set on a slight incline. Along the inside of the shell, running parallel to the axis of rotation, are fixed radial shelves which continually lift and drop the material in its passage through, thus giving uniform mixing and heating. The gypsum is not ground fine as the dust losses would be too great, but is broken into pieces about the size of a walnut, the grinding being effected after calcination. The actual time that the gypsum is heated is much less than with the kettle system or any other discontinuous process.

In the Cummer Dryer the gypsum is crushed to about $\frac{3}{4}''$ size and enters the cylinder at the front and higher end, being fed in at a regular rate by mechanical means. Hot gases from the furnace, which is equipped with a mechanical stoker, pass into the commingling chamber, which extends under the entire length of the cylinder. At the same time, sufficient air is admitted through openings, and, passing through the brick arch under the commingling chamber, mixes with the hot furnace gases, the exact amount of air being regulated by dampers, so that the mixture of gases and air has a temperature best suited to the material. The cylinder has a number of hooded openings, so arranged that the hot gases and air coming from the commingling chamber, are drawn by a fan into the cylinder, where they meet the gypsum which has entered the calciner at its front end. The waste gases from the cylinder are drawn off by the fan and passed through a dust room into the atmosphere. The hot material is discharged at the lower end of the cylinder and is continually removed by a screw conveyor, the temperature of the material on discharge being recorded by a thermometer, so that a uniform product can be obtained by adjustment. It is claimed that this temperature can be controlled to within 5°C. In this process all the hygroscopic moisture, but only part of the water of crystallisation, is removed. The gypsum remains in the rotary for only 10 minutes and as it leaves is steaming and uniformly heated to a temperature, which, according to Messrs. Cummer, varies from 200° to 300°. This is a surface temperature only. In the lump, dehydration to hemi-hydrate occurs at temperatures much below this. It is then elevated into calcining bins of

brick or wood, brick lined, where calcination is completed in about 36 hours, due to the heat remaining in the material. To ensure continuity of working four bins are used. When the material is cool, it is ground.

The Cummer machine has found a far greater use as a dryer than as a calciner and in fact, the manufacture of the calcining plant has been discontinued by the makers. There are, however, six such mills in existence, with a combined capacity of 1,000 tons of plaster a day.

The Mannheim Calciner. This rotary calciner was in use in 1901, at the works of the Rhenish Gypsum Company, near Mannheim, Germany, and a description of it is given by A. F. Wilder in Gypsum Industry in Germany, which forms part of volume XII of the *Iowa Geological Survey.*

A fire box, with an automatic stoker and using forced draught from a fan, is placed in front of a brick chamber in which is a rotating cylinder fitted with the usual shelves. Above the chamber is a forewarmer through which the raw, crushed gypsum is carried by a spiral conveyor, and finally dropped into the rotating cylinder below and at the same end as the fire. The hot gases, under a forced draught, strike the gypsum as it falls from the shelves and move the particles forward with a speed directly proportional to their size. Thus the coarser material moves more deliberately and is heated more than the finer, which is blown along at a higher speed. The hot gases pass out of the cylinder, by a suitable pipe, to the forewarmer which they enter at the same end as the raw gypsum. Apparently in both the calciner and forewarmer the gases and material run in parallel flow, whereas in ordinary rotating dryers counter flow is more usual. The calcined material passes out at the back end of the cylinder and is elevated to an upper floor, where it is cooled in a spiral conveyor with a water jacket. It is stated that the gases leaving the forewarmer are at a temperature of only 80°C., and that one ton of gypsum requires only 100 lbs. of inferior coal. A dust chamber is provided between the forewarmer and the chimney and no dust was seen outside the mills or on the roofs. The plaster is ground after calcination.

Another rotary calciner is described by Winterbottom in "*Gypsum and Plaster of Paris*, Bulletin No. 7, Department of Chemistry, South Australia," as being used by the Austral Plaster Co. This calciner is 50 feet long and 5 feet diam., and has a firebox at each end, the flue being situated about the middle of the length of the cylinder, so that the latter can be heated both internally and externally. The cylinder is set at a slight incline and the raw gypsum, entering at the top end, gravitates to the lower, being cascaded as usual by shelves. Calcination is not completed in the cylinder, but, as in the Cummer process, the hot material is elevated into calcining bins, where it is left for several days to cool. After cooling, it is ground. The output is about one ton of finished

plaster per hour. Coke is used as fuel.

In this calciner the gypsum, which has been previously washed and dried, is much finer than that used in the Cummer dryer. Before washing, sieving showed 37% left on 10 mesh, 18% on 20 mesh, 17% on 40 mesh, 7% on 60% and over 20% passed through 60 mesh. A sample, examined by Winterbottom, from the hot material leaving the calciner, showed 2·49% water, indicating that there was a large amount of soluble anhydrite formed.

Kilns and Ovens. In Germany, according to A. F. Wilder (loc. cit.), in 1901, some gypsum was calcined specially for the porcelain trade, in ovens like those used by bakers in which the gypsum is agitated by long pokers. He believes that "it is more tradition than anything else which leads calciners to adhere to extremely expensive and ancient methods, although it is generally admitted that this method is not necessary to produce a plaster of the quality required." Most of the porcelain gypsum and much stuck gypsum (gypsum plaster) is made in this way. These primitive ovens have probably been discarded since. Wilder describes several kilns for calcination of gypsum :—"Long rooms with thick walls are constructed out of brick. These rooms have a height of seven feet and are built above a furnace. On the floor of the room, and extending out for some distance in front of it, is a car track. Cars three feet wide, carrying a rack with five or more shelves are loaded with gypsum and run into the rooms. The gypsum is previously crushed, but not ground, the fragments varying in diameter from an inch to $\frac{1}{4}$ inch. The shelves are loaded and unloaded by hand. The smoke and gases from the furnace do not enter the room containing the gypsum, but pass through the walls in flues. From 30 to 36 hours are required for calcining. The room is kept at a uniform temperature of 140°C., and long thermometers inserted through the walls indicate the temperature at any time. An ordinary oven is emptied three times a week and furnishes each time 8 to 9 tons of calcined gypsum."

It is claimed that one ton of gypsum requires 120 lbs. of bituminous coal which, as Wilder remarks, is entirely too low. The Bock kiln is continuous and consists of a tunnel through which cars of gypsum are moved by a chain. The fire is confined to the centre of the chamber so that fresh gypsum is gradually warmed at one end, while at the other end, the calcined material is cooling. Kilns, where the heat from a fire passes directly through large pieces of gypsum rock, are found in the old Scanegatty type and the Dumesnil kiln, the latter being an improvement on the Scanegatty. In England, in a few cases, ovens are employed for the manufacture of the so-called "baked" plaster where gypsum crushed to about the size of a hen's egg is placed on trays in an oven.

Comparison of the various Processes. It is difficult to establish any very accurate comparison between the various processes described for the manufacture of plaster, since all the information

that one would like is not available, and also because the particular methods vary more or less amongst themselves. As regards the power required for equal outputs, kilns with direct heat on the gypsum probably require the least, since only grinding is needed, and that is low because, not only are the lumps considerably shattered, but also the grinding of calcined gypsum needs less power than uncalcined material. In ovens without direct heating, the gypsum is crushed before, and ground after calcination so that more power is needed. Rotary calciners work continuously, whereas kettles and open pans are usually stopped at night, so that comparison is difficult. A Cummer dryer will make 50 tons of plaster in 24 hours and would need for the complete installation of dryer, crushers, grinders, elevators, etc., probably about 50–60 H.P. The dryer itself only needs 6–7 H.P. A kettle installation with kettles, dryers, crushers, grinders, elevators, etc., would probably need about 2 to 2·2 H.P. per ton of plaster.

The English open pans complete with grinders would probably require more power than the American system, though not very much. The English do not dry before grinding as is usual in America, and therefore the wet gypsum needs more power to grind, the power absorbed by the American dryer being small. On the other hand, the American mill grinds the rock finer (80% through 100 mesh) so that probably there is little in it. The power required during calcination is less for the kettles than for the open pans, for, although we have no exact data for the open pans, yet it is reasonable to assume that the horse power needed for a kettle is less than that for several 22-foot diameter pans, which would be required to give the same amount of plaster. Moreover, an open pan might just work four runs in the 12 hours, while the kettles could easily work four runs with a much greater output. In America, far more use is made, also, of conveyors and elevators than in England.

Fuel. Here again there are gaps which are difficult to fill. The figures for kilns given in "Gypsum in Germany," by A. F. Wilder, viz.: 120 lbs. of coal per ton of gypsum, is, undoubtedly too low, as Wilder remarks. We have found no other information on the fuel for kilns or for the "baked" plaster ovens. Rotary calciners consume but little fuel. Per ton of gypsum the Perin type in Paris uses 62 lbs., the Cummer 70 lbs. and the Mannheim 100 lbs., but as inferior coal was used in the last type, it is reasonable to take 70–80 lbs. as a fair figure for rotary calciners. The kettle system requires from 90 to 160 lbs. per ton of gypsum, rising, in bad cases, to nearly 200 lbs. The lower figures are for forced draught. In fuel consumption, the English system compares very unfavourably with the others discussed, as it must do when we consider that the heat from the hot gases has to pass through at least $4\frac{1}{2}$ inches of firebrick and then through 2 inches of cast iron or firebrick tile. A figure given to us recently is no less than 480 lbs. per ton of gypsum, but as the coal used was not of the best, probably 400 lbs.

is more correct, although the figure of 450 lbs. of coal has been stated.

Remarks on the English System. The English system of calcination, as exemplified by the open pan system, is open to criticism. In the first instance, the process is exceedingly dusty. Since all the steam escaping from the material, together with the fine dust, can permeate the atmosphere in the shed without let or hindrance, the average conditions are not of the best, since ventilation is not generally a matter of primary consideration. This dust settles on the floor, on the rafters and in fact, on all more or less horizontal surfaces. Waste is obvious, although the floors are swept at intervals to recover the plaster. This dust must be injurious to the health and it has been experimentally proved that it gives rise to bronchial affections and to conjunctivitis.

The chief criticism, however, can be made on the amount of fuel that is consumed, which reaches a high figure. The amount of coal already given, viz. : 480 lbs. is very great indeed, and although this was not a particularly good coal, yet, from other sources we gather that the coal used is on the average 350–400 lbs. per ton of gypsum. At 350 lbs., the coal used is three times good, but not best, American practice, and almost five times that used in rotary calciners. But in addition to the fuel used in calcining, these open pans must be fired all night to keep the brickwork hot, otherwise time is lost in starting up the next day. This is not necessary with kettles where the heat in the brickwork is more easily retained than in the open pans, and where there is a large amount of surface exposed to cooling. The space required for the pans is considerable, yet the output is low. A pan 22 foot diameter treats 4 tons of gypsum in 4 hrs. from charging to discharging, or 12 tons in 12 hours, while a kettle 14 foot diameter *over the brickwork* (*i.e.*, kettle 10 foot diameter) can treat 35–36 tons in 11 hours. The open-pan system seems to be firmly rooted, and it is not possible to expect that a manufacturer using these pans would be anxious to abolish them altogether and replace them by another type. But we believe that a very considerable improvement could be effected by the substitution of gas firing, for this involves no alteration to the pans or their setting other than removal of the existing firing arrangements. All the coal then goes to one spot, the gas producer, the ashes are also concentrated and the producer plant can be outside the calcining shed itself. There is no doubt that producer gas firing can give a much more even heating than a coal fire and at considerably less cost.

Applications of Plaster. The applications of plaster are manifold and fresh uses are continually being found. We propose merely to enumerate the chief uses to which plaster is put in this country, and to deal more fully with some of the newer applications. Plaster is used in dentistry for making casts and taking impressions; in surgery for casts and orthopedic bandages; for statuary and other

art work in museums for making casts of original work; in the pottery and terra cotta trades for moulds, where it is especially valuable on account of its porosity; in plate glass manufacture as a bed for the glass while being ground; in the hat trade as a block on which hats are shaped; and in the jewel trade for holding stones while being polished. The largest use is, of course, for interior decoration of buildings, roofs, walls, and so forth. We cannot discuss these, as we propose to deal with more recent applications of plaster, applications which have not yet been fully appreciated in this country, namely, plaster boards, gypsum tiles and reinforced gypsum.

Gypsum Plaster Boards. The manufacture of gypsum plaster boards originated in Germany, and these boards are extensively used as a substitute, and a greatly superior substitute, for the ordinary lath and plaster so commonly employed in this and other countries. The manufacture of these articles was taken up in America, and they are now being extensively used. The output is being steadily increased as the great utility of the boards for fire protection is being realised. Essentially, plaster boards are sheets of plaster mixed with a fibrous binding material which is added to give the necessary strength and toughness. The fibrous materials added include jute, rushes, tough paper, and woodfelt, in some cases sawdust is used. Originally the boards were made by hand, but with increasing output, the labour has been greatly reduced by devising efficient continuous machines. In America, two types have been evolved, the long, fast running and the short, slow running types, the method employed being the same in both cases. The difference lies in the opportunity given to the plaster to set before reaching the delivery end of the machine. A plaster board machine is a belt conveyor on to which are fed alternately sheets of paper or wool-felt and streams of gypsum plaster. The conveyor belt, which is about 3 feet wide, receives first a sheet of wool felt or tough paper fed continuously from a large reel. On this is spread a layer of wet gypsum plaster. These, with a second sheet of binding material from a roll suspended above, are fed between rollers which squeeze the plaster back and allow only a given thickness to pass between them.

In making three ply or four ply board this operation is repeated the necessary number of times. The gypsum plaster is fed automatically on to a concave belt conveyor, wet with warm water and stirred by mechanical stirrers, so that it spills on to the binding material in a steady stream. In long, fast running machines, which may be 600 to 800 feet in length, the moving board is perforated by a suitable device at that particular place in its travel where the plaster is beginning to set. Short, slow running machines vary from 20 to 80 feet in length, and at the delivery end there is a travelling circular saw or knife which cuts the moving board off square. The boards as delivered from the machine are damp, and the plaster is not completely set. They are loaded on trucks

and passed slowly through a drying room, or each board is set in a light wooden frame, hung on a slow moving belt which carries it through a dryer. The finished boards are stored in warehouses since they must be kept dry. In America, plaster boards are usually 32 inches by 36 inches and are made $\frac{1}{4}$, $\frac{3}{8}$, and $\frac{1}{2}$ inch in thickness.

The wood-felt or paper binding material on the outside is excellent for the application of gypsum plaster, since the small needle crystals of the plaster penetrate and interlace with it and the plaster forming the board, making a very strong bond. The boards can be easily and quickly nailed on to the supports, and being strong and tough, and, in addition to many other advantages, exceedingly fireproof, thére is no doubt that if their manifold uses were realised in this country, both by the manufacturer and the ussr, a further use for plaster would be started with advantage to all.

Gypsum Tiles. As Germany was the originator of gypsum boards, so in that country were these boards developed in thickness, in order that by suitable dovetailing they could stand upright without any screwing or nailing to supports, as is needed in the case of the thinner boards. In this case the thickness would be as much as 12 cm., the joints being filled in with plaster. In America, following the example set by Germany, gypsum tiles are made and used for partitions, floors, roofs, &c. Their use is increasing, and their advantages are many. They are lighter than the same articles in clay; are straight and true, can be cut with a handsaw; are fire and sound resistant, non-conductors of heat, and on account of their light weight and large size, can be laid rapidly. Although originally made by hand, increasing demand has led to the adoption of a suitable machine, which considerably reduces the labour.

This machine is essentially a continuous belt of moulds all of the same size, which are filled automatically with plaster from a mechanical mixer. The necessary holes in the tiles are also put in automatically. This is effected by running the heads of the tapered metal cores in a groove which approaches and recedes from the main belt carrying the moulds. Thus, when the plaster is poured into the mould, the cores occupy their correct position, but as the mould leaves the filling spot, the groove carrying the metal cores recedes from the main belt and the cores are withdrawn. The plant is worked by three men, one to level the plaster in the freshly filled moulds, one to remove the set tile from the machine, and one to grease the withdrawn cores. In an arid climate, blocks of gypsum plaster can be used for exterior construction, and have been built in Douglas, Arizona, where it is estimated that there is a saving of 25% over similar buildings in brick. On account of the size of the blocks, the walls can be laid faster and less skilful labour can be used. Although the use of plaster for outside work in this country is out of the question, except for exhibitions and

purely temporary work, there is no doubt quite an extensive field for the use of gypsum tiles or bricks for interior partition walls.

Floors and Roofs of Reinforced Gypsum. The heading of this section is the title of a paper by Virgil. G. Marani, M.Am. Soc. C.E., who is Chief Engineer to the Gypsum Industries Association in America. The article in question, appeared originally in the *Engineering World* of Chicago, in March, 1922.

There are two very different principles of design involved in the use of reinforced gypsum constructions, the Suspension System and the Plain Reinforced or Structural Reinforced.

In the Suspension System, the reinforcement employed is not dependent on the gypsum mass for the full development of its tensile strength, but must be secured, (independently of the gypsum) to the supporting construction. Before pouring in the gypsum this reinforcement is brought into tension and is temporarily secured to the form work to maintain this necessary condition until the plaster has been poured in and is set. The Structural System, on the other hand, is dependent on the gypsum for the development of its tensile strength, and differs from the Suspension system in that there is no need to secure the steel wires, forming the reinforcement, to the supporting construction. The Suspension system is usually cast in place, although it can be precast at the works, while the Structural system is more frequently precast at the works although it may also be cast in place. Structural Systems appeal particularly where speed of erection is an important factor and it is interesting to note that this system has been developed to cover spans up to 10 feet.

Testing and Standardisation of Plaster. Commercial plasters can vary widely in chemical composition according to the temperature and time of calcination.

In the commercial article may be found the following compounds :—

(1). Unchanged gypsum.
(2). Hemihydrate.
(3). Anhydrous calcium sulphate in the following forms :
  (*A*). Soluble anhydrite which readily absorbs water and reverts to the hemihydrate.
  (*B*). Slow setting anhydrite which absorbs water slowly and sets with hardening.
  (*C*). Dead burnt plaster and anhydrite which do not rehydrate with water.

Plaster prepared at controlled temperatures below about 150°C., consist mainly of hemihydrate, soluble anhydrite and a small amount of unchanged gypsum, but on keeping, the soluble anhydrite changes to hemihydrate and the product becomes mainly hemihydrate and some unchanged gypsum. At higher controlled temperatures up to about 270°, as in the continuous rotary processes, the plaster consists mainly of soluble anhydrite, some slow setting

anhydrite and a small amount of gypsum, and, after keeping, is composed mainly of hemihydrate, slow setting anhydrite and traces of gypsum. Plasters made by processes in which the flames come into direct contact with the gypsum, and where local overheating occurs, also contain the dead burnt variety, so that the resulting product after standing consists of hemihydrate, some slow setting anhydrite and dead burnt plaster, together with traces of gypsum. In addition to these, all commercial plasters contain hygroscopic moisture and impurities. Since plasters may contain these different constituents with varying properties, they will vary physically and chemically according to the relative proportions of these different components present. Thus, a plaster containing a high proportion of unchanged gypsum, which acts as an accelerator, will set in a short time, while a plaster with a relatively high proportion of slow setting anhydrite and practically no gypsum, will set at a much slower rate, since the slow setting anhydrite acts as a retarder. Taking into consideration also variations in the state of subdivision and the varying effects of the natural impurities present, it is obvious that the properties of commercial plasters must vary within wide limits. There seems to be little attempt in this country to define strictly the various qualities of plaster on the market, and such crude classifications as are recognised in the Trade, appear to have been developed from long trade custom and usage rather than from any clear definition of quality.

The commercial value of plaster depends upon the property of setting with water to a hard mass, and the generally accepted explanation of the phenomena of the *setting of plaster* was put forward by Le Châtelier in 1887. He considered that the setting with water was due to the formation of a supersaturated solution of the half-hydrate from which small crystals of gypsum separated. This was followed by the solution of more hemihydrate, which, in its turn, was deposited as gypsum; this process of alternate solution of hemihydrate and deposition of gypsum being continued until all the hemihydrate was converted into a compact mass of minute crystals of gypsum.

The Final Setting Point of the mass would obviously be that point at which the crystallisation is complete. In addition to this, however, the Trade recognise another, but somewhat vague point in the setting, known as the *Initial Set.* Although the use to which commercial plasters are applied depends to a large extent on the time taken for the plaster to reach this initial set, there is, in this country at any rate, no recognised definition of this point or of the methods employed in judging it.

Each manufacturer has his own idea of what the initial set means and has his own particular method of testing. Perhaps the best definition of the *Initial Setting Point* we can offer is that given to us by a leading plaster firm, viz.: "The initial set is the time taken for plaster, when made into a thin cream with water, to become

of a workable consistency." Since plaster when setting remains at a "workable consistency" for an appreciable period, and as the time will also depend on the original consistency of the "thin cream," *i.e.*, the relative proportions of plaster and water, to which little attention appears to be paid, it will be realised that the Initial Setting Time as at present understood is a very vague term indeed. In a comparative test of the various methods employed for fixing this point we have found differences of as much as 30–40%. The same remarks apply to the determination of the final setting point. Not only from a scientific point of view, but also from a utilitarian standpoint would it be of advantage to standardise throughout the trade the various tests employed.

The importance of this was recognised in Germany as far back as 1911 when the German Plaster Association at Berlin, working in conjunction with delegates from Switzerland, Hungary and Russia, proposed a series of standard tests for fineness, gauging, time of setting and tensile strength. In America, a similar movement is on foot, and the American Society of Testing Materials, at the instigation of the Gypsum Products Association, have issued a series of standard specifications for gypsum plasters.

We believe that it would be a distinct advantage if the Gypsum Association of this country were to work along similar lines and adopt a series of standards for their products and standardise the methods of testing the products. As the great advantages of plaster boards, plaster tiles and reinforced gypsum work become more and more recognised and applied in the constructionof fire proof buildings, such a standardisation will become an absolute necessity, as was found to be the case some years ago with Portland cement. In view of the confusion existing in the plaster trade in this connection, and at a time when manufacturers are seeking further outlets for their wares, which might well be along the lines we have indicated, we feel that the plaster manufacturers could not do better than standardise their products upon a sound scientific basis.

DISCUSSION.

THE CHAIRMAN:—So far as the Potteries are concerned, we quite agree that plaster does differ within wide limits. At the same time, we in the Potteries are in the position that we have no standards to give to the plaster manufacturers. I have found from my short experience, that what pleases one manufacturer does not always please his next door neighbour. Therefore, the plaster manufacturers go their own way, and, unfortunately, even when they are going their own way, there is the human element to deal with. Although I believe that all the English producers of plaster manufacture by one method, the results from week to week are not consistent. I have not been able to assimilate all the facts that have been mentioned by the lecturer, but I have come to the

conclusion that there is a good deal of chance for variation in plaster, and this is borne out by the results that we manufacturers experience in practice.

Mr. W. Lindley:—Is it possible to revive old moulds, or to bring the plaster used up in them back to its original properties and prestige?

Mr. D. F. W. Bishop, M.A.:—I have much pleasure in moving a vote of thanks to the authors for their valuable paper. One of the usual penalties of the unhappy individual who is public spirited enough to undertake the duty of proposing a vote of thanks to a lecturer is, generally speaking, to see all the facts that he wishes to comment upon taken from him one by one by a whole string of questioners, so that finally he gets up stark naked, metaphorically speaking, having all his points shred from him. I cannot say that that has been the case tonight, for the time has not permitted a long discussion. I am not, therefore, in quite the usual predicament, except for the one interesting point that my friend, Mr. Lindley, has put before the lecturer, and if we get an official answer to this I shall be rather surprised.

I should have liked to have asked the lecturers whether there is any difference in the quality or the working properties of plaster of Paris, not only as produced by the English, German and American methods, but also as prepared at the different temperatures. One fact is impressed upon us strongly by the interesting lantern slides which we have seen this evening. The burning shed illustrates only one of the instances, which we meet continually on a pottery, of theory and practice going hand in hand. The lecturer said that plaster shows very bad conductivity. I think those who have had anything at all to do with ovens will bear me out, speaking from rule of thumb methods, that plaster serves us in good stead in the direction of stopping the oven bars from burning through. This is simply an illustration of practice bearing out theory.

I was very much interested to hear the lecturer mention the various applications to which plaster is being put in the United States, and to some extent, I gather, in Germany also. I was rather struck with the information that plaster is now being used for floors. I would rather like to know whether, for floors used for heavy traffic, plaster blocks have proved successful.

At this late hour, I do not wish to raise much discussion. I will, therefore, close by proposing a very hearty vote of thanks to the lecturer and his colleague for their most interesting paper.

Mr. Arthur Heath:—It is perhaps rather appropriate that I should second this vote of thanks, which I do with very great pleasure, since it is just possible that I am the only one present who is primarily interested in the gypsum industry.

In the first place, perhaps I may be permitted to say, in regard to Mr. Bishop's question concerning plaster flooring, that we have

used nothing else for this purpose at Newark-on-Trent for the past 60 years. The floors require scarcely any repairs, though there are fairly heavy weights continually passing over them. America is not the only place, therefore, where plaster flooring blocks are made.

I do not think anyone present has been down to our Newark-on-Trent works lately, but I would just like to say that a party went down recently, and they saw there a shed about 300 yards long containing a continuous machine, working at full pressure, making partition blocks, which are being very largely used in this country at the present time.

There are many interesting questions as to whether the kettle system is the best for the manufacture of plaster. I am not a practical man at the works and so I am only speaking now from what I have surmised, when I say that a kettle does not give such uniform results as the old-fashioned pans, which have only a very shallow depth. One would naturally expect to get more uniformity from a shallow bottom pan than from the thick bed of gypsum which is put into a kettle.

With regard to the other point, as to whether baked plaster is better than boiled, I would like to point out that, in this district, there has always been a distinct prejudice against baked plaster. My firm could never sell it. If you had offered to *give* it to a manufacturer at one time, he would not have taken it. But there came a time when nothing else could be got, and then some of the manufacturers tried it, with rather encouraging results. Boiled plaster is preferred, for the simple reason that it is cheaper.

There are a good many other points in the paper which one would like to look into more closely. I propose to read it through, after which I might wish to send a few questions to the essayists, to be answered by them through the post.

MR. BRITTAIN:—With regard to the question that was raised about old moulds, I would like to point out that, if the moulds used are of pure gypsum plaster, without, as is usually the case, admixture with any other material, and they are kept fairly clean, I see no reason why, if they are ground again, they cannot be re-boiled and used over again. The product would probably be quite a good plaster, although it is possible that it might not be quite so good for pottery purposes as the original. A good deal would depend on the condition of the moulds prior to regrinding. In any case, the moulds would have to be thoroughly washed free from clay and dirt before treatment. In view of the expense this would entail, it is doubtful whether reboiling old moulds would be a profitable operation.

In reply to the question as to the difference in the qualities of plaster made by the various methods, I may say that it is true that there are differences. The initial setting time of American plaster is usually reckoned to be from 20 to 25 minutes, and a representative

of the American Gypsum Association, who was over in this country a short time ago, is credited with the statement that properly calcined plaster will not set in less than 25 minutes. If that is so, then we in England do not make proper plaster at all, and we do not know how to make it. As a matter of fact, the setting of plaster depends to a great extent on the amount of free gypsum there is in it. Properly calcined plaster, even if made in the laboratory, and made at a temperature of 120 degrees, will not set in less than 25 minutes. By setting I mean mixing to a fairly thin state and then testing with a Vicat machine, such as is used in the Portland cement industry. The American setting is about 25 minutes *under these conditions*, when the plaster is more or less of a workable consistency. But in England the commercial setting time varies from 5 to 10 or 12 minutes, and I attribute that to the fact that, at the lower temperature, there are some particles of unchanged gypsum, which tend to set the crystalisation going, this resulting in a quicker setting.

With regard to the point as to whether the manufacture of plaster by the kettle system is the best, the Americans would say so undoubtedly. The English manufacturer would dispute this. I had better, therefore, refrain from attempting to say which is the better of the two.

VII.—Atmospheric Conditions in Potters' Shops and the Efficiency of Various Types of Drying Stoves.*

By H. M. Vernon, M.A., M.D., Investigator for the Industrial Fatigue Research Board.

THE investigation to be described may be said to have been initiated by the National Council of the Pottery Industry, for in 1920 this Council invited the Industrial Fatigue Research Board to investigate questions of fatigue in the Pottery Industry, and, as a result, I was entrusted with the work, with the assistance of Mr. T. Bedford. I was fortunate in receiving much advice and help from a Sub-Committee nominated by the National Council.

The first point that struck me in my visits to potters' shops was their high temperature, as compared with what I had experienced in the workshops of a number of other industries, so I thought it worth while to collect numerical evidence on the subject. To this end, Mr. Bedford and I made systematic observations, both in summer and winter, on the temperature and ventilation of the shops in the pottery works suggested to us by the Committee. Before describing the results we obtained, I will refer to some observations made in other industries, since they will serve as a basis of comparison. During the war, I investigated the temperatures at a large fuse factory of over 9,000 workers, for some months, and the average temperatures observed in two of the shops are shown in Fig. 1. In the smaller shop, which was about 200 ft. square,

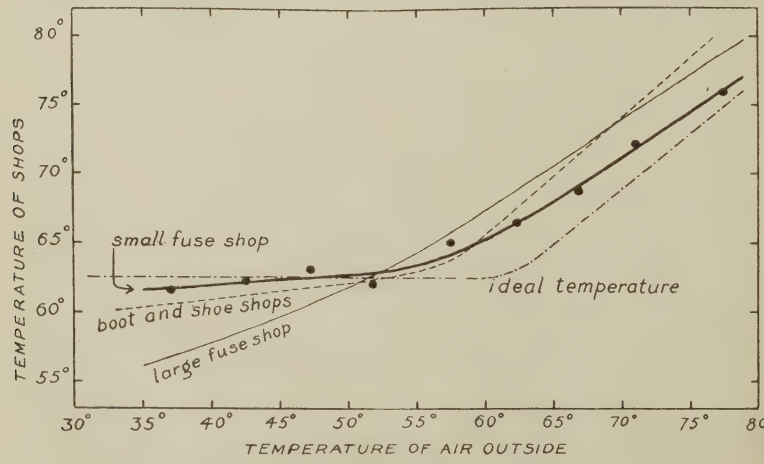


Fig. 1.

Temperatures in Engineering Shops and in Boot and Shoe Shops.

*We are indebted to the Controller, H.M. Stationery Office, for permission to reproduce portions of Report 18 of the Industrial Fatigue Research Board.

it will be seen that when the outdoor temperature was 37°, the shop temperature was 62°, and when the outdoor temperature was 42°, 47° or 52°, the shop temperature was still only about 63°. Then, as the outdoor temperature rose to 57° and 62°, the shop temperature went up a little, but it was only 66° when the outdoor temperature was 62°. That is to say, this fuse shop was maintained at a nearly constant temperature of 60° to 65° right through the autumn, winter and spring, and only on warm summer days did its temperature rise much. When the outdoor temperature was at 77°, the shop temperature was only at 76°, as the heat took some time to penetrate built factory walls. It is probable that a temperature of 60° to 65° is the most suitable for industrial workers engaged on moderately active work, so I regard the temperatures observed in this fuse shop as almost ideal. The dotted line curve shows the average temperatures observed by Hambly and Bedford in 35 boot and shoe factories, and you will see that in winter time the shops were a degree or two colder than the fuse shop, whilst in summer time, they were about three degrees hotter. Still, their temperature was reasonably well regulated. In the large fuse shop, however, it can be seen from the curve that the temperature was distinctly too low in the winter.

Passing to the potters' shop observations, we see in Fig. 2 the means of the observations made in shops provided with leaf and

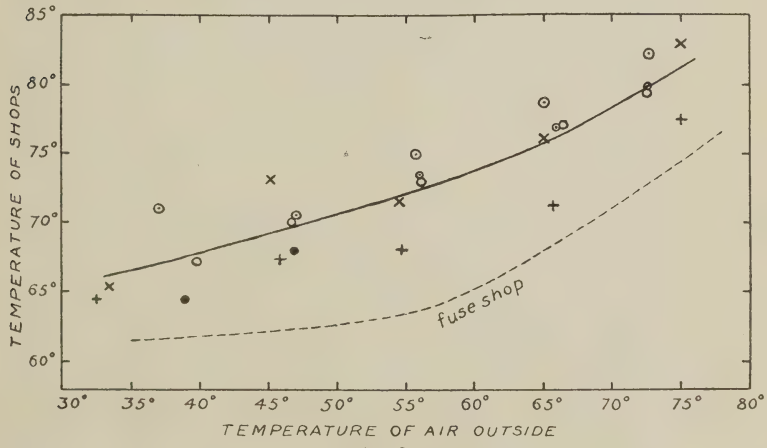


Fig. 2.

Temperatures in Shops fitted with Leaf and with Draw-out Stoves

draw-out stoves. The different signs represent different shops, and each is a mean of about five observations. The temperature curve obtained at the smaller fuse shop is given for comparison, and it will be seen that in every case the potters' shops were considerably hotter. Their temperature was about 67° to 70° in the

winter, and 75° to 82° in the summer, and it may be said that their average temperature was about 7° higher than that of the fuse shop at all times of the year. Fig. 3 shows the means of the

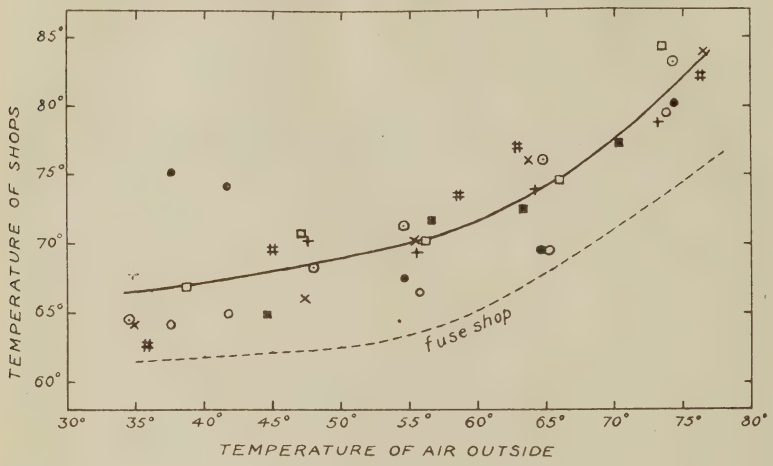


Fig. 3.
Temperatures in Shops fitted with Dobbin Stoves.

observations made in shops provided with Dobbin stoves, and the mean curve indicates that the temperature was about 6° higher than that in the fuse shop. Fig. 4 shows some of the observations made

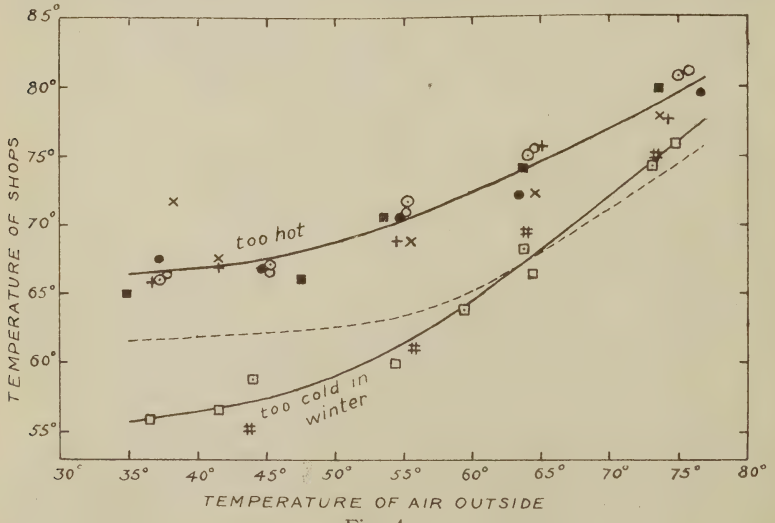


Fig. 4.
Temperatures in overheated and underheated Shops fitted with Chamber Stoves.

in chamber stove shops. The upper curve relates to six shops, and in them the temperature was 5° to 7° above that of the fuse shop, but the lower curve, which relates to three shops, shows that, whilst they were not too hot in the summer, they were distinctly too cool in the winter, as the temperature sometimes fell to 55°. In seven of the chamber stove shops investigated, the temperature conformed fairly well to that observed at the fuse shop, and in shops provided with cabinet stoves the temperatures were likewise fairly reasonable, except on cold days in winter time, when they fell to 55° or less, and were, therefore, distinctly too cold.

The high temperatures appear to have been due largely to the wishes of the potters themselves. We ascertained this by noting down the state of the windows whenever we went into a shop to make temperature observations. Any window or skylight which was incapable of being opened we ignored in our calculations. Our results showed that in shops provided with leaf or draw-out stoves, the average shop temperature was 66·5° when the out-door temperature was at 36·3°, or a little above freezing point. Almost all the windows were of the hopper type, and we found that 88 per cent. of them were shut up completely, whilst 8 per cent. of them were in the half-open position, and 4 per cent. of them were fully open. If we suppose that a fully open window admits about twice as much ventilation as a half open one, we may say that half of 8, or 4, + 4 = 8 per cent. altogether of the available window space was open. When the outdoor temperature was at 46·3°, the average shop temperature was 70°, and yet we found that the potters opened only 11 per cent. of their available window space. So it is evident that they *liked* this shop temperature of 70°. When the shop temperature rose to 72°, they began to find it a little warm, for they opened 31 per cent. of the available window space, and when it rose to 76° they opened 51 per cent. of it, but even with a shop temperature of 80·4° they kept 10 per cent. of their windows shut completely, and 57 per cent. of them half open, so they utilised only 62 per cent. of the available window space. In the dobbin stove shops, they opened 26 per cent. of the window space when the shop temperature was 69°, and 42 per cent. of it when it was 70°, whilst they opened 74 per cent. of it when it reached 81°, so they appeared to desire slightly more ventilation than the potters in the other shops mentioned. Still, it is evident that the potters liked shop temperatures which most industrial workers would regard as oppressively high. Presumably the reason is that the potters come to the works at the age of 14, and they get so acclimatised to the heat that they feel uncomfortable without it ; but it does not follow for this reason that it is good for them. There can be little doubt that they render themselves more susceptible to cold, and when they go into the open air on bitterly cold days in the winter, they are more likely to catch chills than industrial workers employed in less over-heated factories. The

very great mortality of potters from phthisis and other respiratory diseases is generally attributed to the inhalation of pottery dust, but it may be due, in no small degree, to the high temperature and lack of ventilation.

Ventilation. The state of the ventilation was always determined at the same time as the temperature observations were made in the shops, and for this purpose, the *Kata-thermometer*, invented by Dr. Leonard Hill, was employed. This instrument is a large-bulbed alcohol thermometer, which is first heated to a temperature above 100°F. Its rate of cooling from 100° to 95° (on what is approximately the temperature of the human body), is determined by means of a stop watch. From this rate of cooling, and a knowledge of the temperature of the room, it is possible, by means of a simple formula, to calculate the velocity of the air currents impinging on the bulb of the thermometer. It is necessary to make several observations at different places in a workshop, and to take an average, and this average figure affords an accurate idea of the state of ventilation of the shop. As the result of some thousands of observations, we found that in winter time about a third of the velocities were less than 15 ft. per min., and two-thirds of them were less than 20 ft. per min., whilst only 1 per cent. of them were over 40 ft. In summer time the air currents were slightly greater, the median (or middle) velocity amounting to 21 ft. per min., as against 17 ft. in the winter observations. In boot and shoe factories, on the other hand, Hambly and Bedford found that, in winter time, 87 per cent. of the shops had a velocity of 25 ft. or more, and 35 per cent. of them one of 41 ft. or more, whilst the summer velocities were greater still. The median summer velocity was 37 ft. per min., and the winter velocity, 35 ft., or double as much as in potters' shops. That is to say, the potters' shops had only about half as much ventilation as the boot and shoe shops, in spite of their considerably higher temperature. It is not that the boot and shoe shops were over-ventilated, but the potters' shops were badly under-ventilated, largely because of the habit of the potters in keeping their windows shut.

Humidity. The air in potters' shops contains a considerable amount of moisture derived from the moist clay and from the drying ware in the stoves, and it is often assumed for this reason that the relative humidity of the air is high. To determine this point, Mr. Bedford and I made some thousands of wet bulb readings in potters' shops, and calculated the humidity of the air. The results of these observations are described in detail in Report No. 18 of the Industrial Fatigue Research Board, to which the reader is referred. Our general conclusion was that the humidity of the air in potters' shops is approximately the same as that observed in engineering shops, in boot and shoe shops, and in the outside air at corresponding temperatures. For instance, at a dry bulb temperature of 60° to 70° the air was 62 per cent. saturated, whilst the outside air, at various localities in the country, was 60

to 67 per cent. saturated. It might be thought that this result contradicts the undoubted fact that the shop air contains large quantities of moisture received from the moist clay and the drying ware, but it is not so. Owing to the high temperature to which the air in the shops is heated, it can carry very much more moisture than the outside air without any increase of saturation. For instance, if air half saturated with moisture at 50° is heated to 70°, it can carry 97 per cent. more moisture and still remain half saturated. If heated to 80° it can carry 170 per cent. more moisture, again keeping at half saturation.

The efficiency of various types of Drying Stoves. It is important for us to determine whether these high temperatures in potters' shops are unavoidable, and whether it is not possible to retain the present drying powers of the stoves, and even to increase them, and yet at the same time reduce the flood of hot air which passes from them into the shops. In order to obtain an answer to this question, I made numerous observations on the temperature, humidity and velocity of the air currents in various types of drying stove. The direction of the currents was determined by means of smoke paper, and their velocity, by means of the kata-thermometer and anemometer. It was found that in almost all of the stoves investigated, there was a rapid current of relatively cool air flowing in through the lower part of the entrance, and one of relatively hot air flowing out through the upper part, whilst at some intermediate point, which I term the "neutral point," the air neither flows in or out, but ascends vertically at a slow rate, owing to the heat from the steam pipes on the stove floor. For instance, in a multiple chamber stove with entrances $6\frac{1}{2}$ ft. high and 2 ft. wide, air at a temperature of 70° was found to be rushing in at a velocity of 75 ft. per min. just above floor level. At $1\frac{1}{2}$ ft. above the floor, air at 71° was rushing in at 56 ft. per min. ; $3\frac{1}{2}$ ft. above the floor, air at 74° was neither passing in or out, but was ascending at the low velocity of 27 ft. ; 5 ft. above the floor warm air at 83° was passing out with a velocity of 48 ft., and 6 ft. above the floor air at 85° was rushing out with a velocity of 65 ft. per min. This hot, back draught air was much less saturated with moisture than the inflowing air (viz., 43 per cent. as against 64 per cent.), though it carried a greater weight of water in it (12·6 grm. per cubic metre as against 11·8 grm). Moreover, its drying power was considerably greater. The drying power of air is approximately proportional to the difference between its dry bulb and its wet bulb temperatures, and whilst, at the time the observations were made, the drying power of the air out of doors was only 2·5, that of the air entering the stove from the shop was 7·3, and that of the hot, back draught air was 14·9.

At the time I obtained these results, the stove had no sort of ventilating pipes to the air outside, but an elaborate system of pipes was installed shortly after, and when I repeated my

observations some months later, I found that the air currents were more or less the same, but I was able to calculate that, instead of the whole of the hot, back draught air flowing into the shop, probably about a third of it went up the ventilating pipes. At another works an elaborate system of ventilation was installed, and the ventilator pipes were fitted with "pentarcomb"* openings situated just above the entrance of the stoves. The other ends opened into a 2 ft. shaft provided with an extraction fan, and I calculated that when this fan was running it extracted about a third of all the hot back draught which would otherwise have passed into the shops, and that this third contained about half of the moisture given off by the drying ware in the stoves. When the fan was not running, the shaft and ventilators extracted about a quarter as much air as before, and, as a matter of fact, this was the extent of ventilation usually employed. The men complained that when the fan was on they could not get their ware to dry properly, so it was only set running on hot summer afternoons.

But why, it may be said, did the ventilation caused by the fan prevent the drying of the ware, in spite of the fact that only about a third of the back draught air was carried off? The reason is, that under ordinary circumstances there is a steady circulation of hot, back draught air from the upper portions of the stove into the shop, and this hot air, after being cooled somewhat by the windows and walls of the shop, sinks to the floor, and is again sucked into the stoves. There it gets heated up, and passes out again, but as this circular movement continues, the air, both in the stove and in the shop, tends to get hotter and hotter. Supposing, however, a fraction of the hot, back draught air is carried right away by ventilators, it is replaced by fresh and cold air from the outside, and so the temperature of the shop air, and also of the stove air, is kept down.

Efficient Stoves. The Chamber Stoves just described were evidently not efficient, if by efficiency we mean a stove that dries the ware well, but one which does not, at the same time, allow more than a small amount of hot, back draught air to pass into the shop. However, I came across a few chamber stoves which complied with my definition of efficiency. They were heated by means of coke-burning stove pots of the ordinary type, and these stoves, which generally have a long flue-pipe up which the very hot air from the stove has to pass, extract a very large amount of air. Consequently, there is usually an indraught of air through both the top and bottom of the chamber doors, provided they are only opened a few inches, though they allow an outflow of a certain amount of back draught air if they are wide open. Again, in one very large chamber stove used for the drying of electric fittings, I found that if all the ventilators in the roof were open, they almost entirely prevented back draught into the shop, even though the doorways were wide open. However, these ventilators were only

*See TRANS. **12**, 371, 1913

kept open in the summer. In the winter they appeared to be kept entirely shut, and in consequence, air at a temperature of over 90° was passing back into the shop through the upper half of the doorways.

Dobbin Stoves. None of the Dobbin Stoves which I came across complied with my definition of efficiency, as all of them allowed a great deal of back draught air. The best of them removed more than half this air, as they were provided with large ventilating shafts opening just inside the entrance of each doorway. However, the volume of back draught air could easily have been reduced in all of them by making the revolving dobbins fit more closely to the doorways. This could probably be done most easily by means of wooden strips and partitions edged with felt. The top of the dobbin almost always fitted badly, and left a gap of 6 to 12 inches from the roof of the stove, through which a rapid back draught of hot air passed.

Draw-out Stoves were investigated only at one works, and a photograph of them is reproduced in Fig. 5. It will be seen

Fig. 5. Draw-out Stove, showing three sections completely drawn and one half-drawn.

that three of the sections are completely pulled out, whilst one is half pulled out. The stove was very well constructed, and there was very little back draught air, as the back board of each section, when it was fully pulled out, closed the gap. Nevertheless, I do

not consider this type of stove to be really efficient. Each working potter had four of these sections for drying his ware, and he usually drew out each section, in turn, for 1 to 2 hours in the morning, and he repeated this process later on in the day. Each section contained about 300 moulds, which had a temperature of about 100°F. at the time the section was pulled out, but they had cooled almost to the shop temperature by the time it was pushed in again. That is to say, for each working potter almost the whole of the heat from 8 sections of moulds was dissipated into the air of the shop, and, in consequence, it was considerably overheated.

Leaf Stoves were investigated only at one works, and a photograph of one of them is shown in Fig. 6. The stoves had a high-

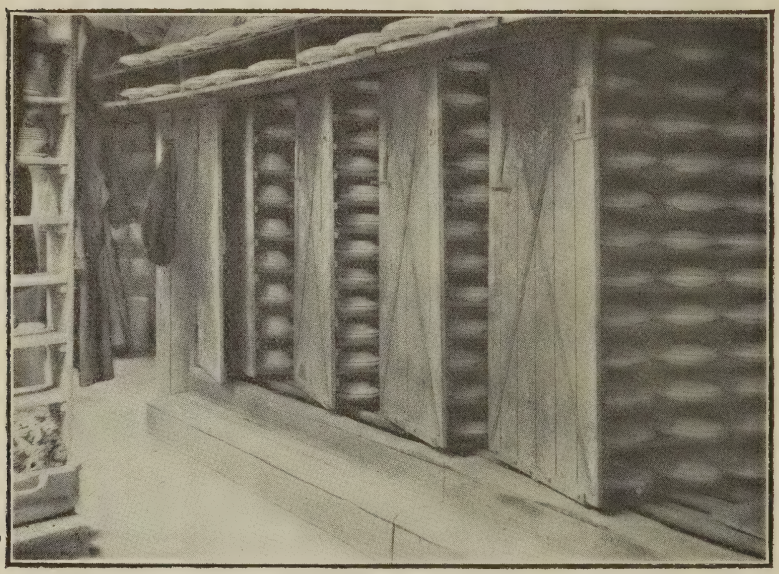


Fig. 6. Leaf Stove showing four leaves and the bed of steam pipes.

pitched roof above them which formed a roomy space into which the hot air could rise, and at the apex of the roof there was a wide 10 ft. shaft ending in a ventilator, through which the air could pass to the outside. In spite of this, back draught air was flowing into the shops through the upper third of the stove entrance at an average rate of about 40 ft. per minute. This hot air, rising from the bed of steam pipes, took the line of least resistance, and it was easier for part of it to pass into the shop and part into the roof, than for all of it to pass into the roof.

Cabinet Stoves were investigated at three works, and a photograph of one of them is shown in Fig. 7. There were 8 sliding

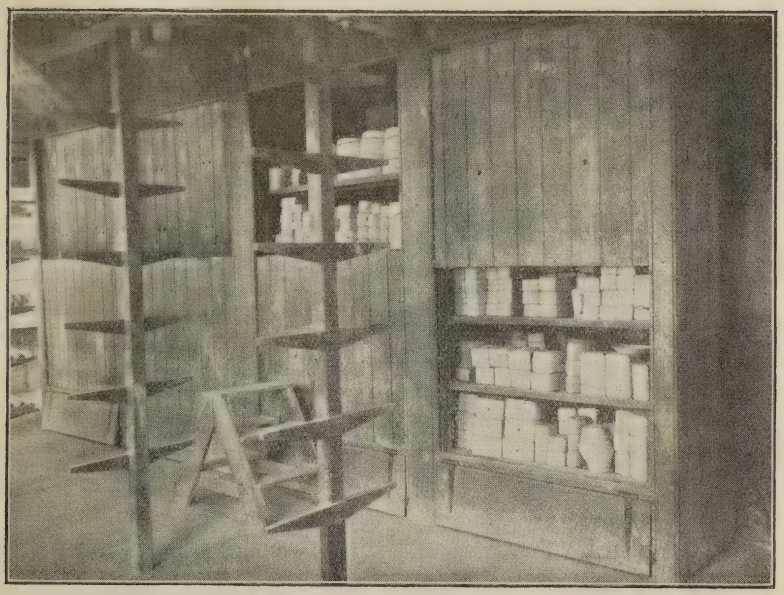


Fig. 7. Cabinet Stove, showing one top and one bottom panel out.

panels on each side, whilst there was a large ventilating shaft leading from the middle of the roof to the air outside, and smaller shafts at each end. This stove was connected with a similar one on the floor beneath, and both of them were used for drying moulds used in the casting of small, fancy china articles. Though the moulds had to be put in or out of the stove frequently, I found that on an average only one or two of the 8 top panels and the same number of the bottom panels were open at a time. When open, there was a moderate in-draught of relatively cool air through the bottom opening, and a moderate back-draught of hot air through the upper opening, but the ventilating shafts were so big that they drew off by far the larger portion of the hot air. In fact, they drew off distinctly too much in the winter, and the temperature of the shops fell to about 55°, as there was no source of heat other than that derived from the stove. In the summer, the shops remained comparatively cool. It would have been advantageous to introduce sliding shutters in the ventilating shafts, which could be opened or closed at will, and thereby a larger volume of back draught air could have been diverted into the shops on cold winter days. This would have warmed the shops without diminishing appreciably the rate at which the moulds dried.

Cabinet stoves, therefore, appear to be more efficient than almost any of the types to which I have so far referred, though they are

not usually considered suitable for drying small earthenware articles such as plates and saucers.

Mangle-Type Stoves. Much more efficient even than these cabinet stoves were the mangle-type stoves seen at one works. Fig. 8 shows one of the double stoves, which was about 19 ft. high

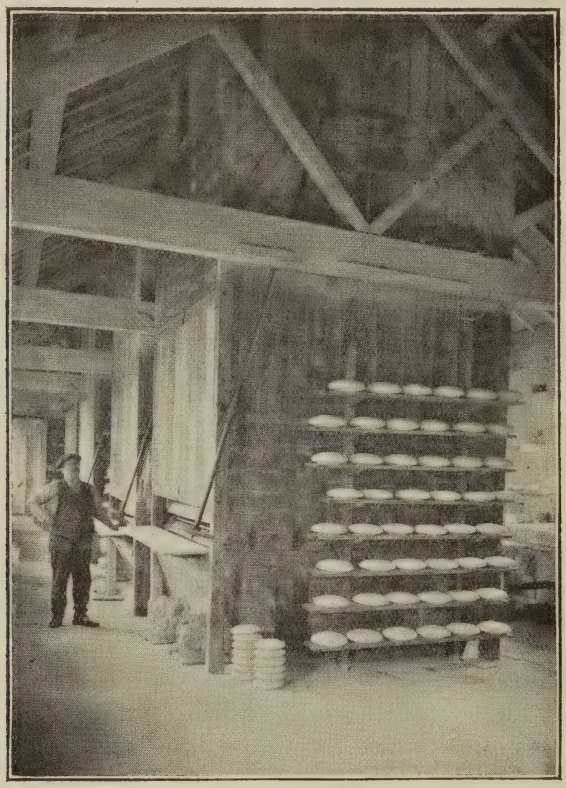


Fig. 8. Mangle-type Stove (Patent applied for No. 1147/1921.)

in the middle, 16 ft. high at the sides, and 7 ft. square. There were two systems of shelves in each stove, suspended by steel rods from chains, which moved over cog wheels at the top and bottom. These shelves could be moved on by means of the worm gear, and owing to mechanical devices they moved easily, without any jerks. About $3\frac{1}{2}$ ft. above floor level there was a flap, which could be turned back to a horizontal position. Access to the shelves was obtained thereby, but no hot air escaped into the shop even if the flaps were left continuously open, as there was always a weak in-draught. The stoves were heated by a system of pipes running vertically from floor

to roof between the two systems of revolving shelves, and the hot air escaped by two narrow gaps between the tiles near the apex of the roof. It will be realised that the moulds of ware, when first placed on the shelves, are exposed to comparatively cool air, but as they ascend the stove they get heated more and more, until they meet the hottest air when they reach the top. On their downward course they gradually transfer their heat to the descending shelves of ware, and by the time they are withdrawn from the stove they have very little surplus heat left. That is to say, practically none of the heat from the steam pipes has a chance of reaching the shop, either directly or indirectly, except through the walls of the stoves. If these were made heat-proof, it would be essential to instal an independent system of heating in the shop, but at the works where these stoves were erected this was not found necessary, so sufficient heat must have leaked through the stove walls.

These mangle-type stoves are not so perfect, in theory, as the American drying stoves described by Allen in 1919, but they are certainly the best I have seen in this country.

Air Velocity and Drying Power. There is much doubt as to the relative parts played by heat and by ventilation in the drying of the ware. The potters themselves, arguing from practical experience, are generally of the opinion that heat is the one requirement necessary, but this view is by no means universal, and Mr. William Burton, in particular, stated that the first principle in drying is to pass a sufficient volume of dry air, but not necessarily very hot air, among the articles to be dried.

The drying of moist clay ware is in some ways comparable to the evaporation of water from a water surface exposed to the air. This subject has been investigated a good deal by meteorologists, and their results seem to show that air currents have only a moderate effect on evaporation. For instance, Bigelow found that if the rate of evaporation in calm air be taken as 100, it is increased only to 107 in a wind of 1 kilometer per hour (55 ft. per min.), to 114 in a wind of 2 kilometers, to 121 in a wind of 3 kilometers, and so on. It might be thought that these figures contradict common experience as to the effect of a breeze on the rapidity with which washing dries when hung on a line, but it is not so. A gentle breeze has a velocity of about 8 miles an hour, and this would nearly double the rate of drying, if Bigelow's figures are correct. Arguing from the estimated velocities of the air currents in the stoves which I investigated, and from other evidence, I calculated that these currents probably increased the rate of drying of the ware by about 20 per cent.; but consider, on the other hand, the effect of high temperature. It can easily be calculated that if air at 60° were heated in a potters' stove to 70°, its drying power would be $2\frac{1}{2}$ times greater than before; but if heated to 80°, it would be $4\frac{1}{2}$ times greater; if to 90°, 7 times greater, and if to 100°, no less than 10 times greater. Supposing, therefore, that we have a fixed

amount of heat available from the steam pipes in a stove, and that we can utilise this heat either to warm 1 volume of air from 60° to 100°, or 4 volumes of air from 60° to 70°, there can be no doubt what we should do if we wished for rapid drying. It can be calculated (see Report) that the large volume of cooler air would have only a quarter as much drying power as the small volume of hot air.

However, you may be inclined to doubt these theoretical conclusions, which are based on meteorological observations, so I tried to obtain more direct evidence by some actual drying experiments. First of all, I wanted to find out what happened in the course of ordinary drying, so I inserted the bulb of a thermometer just under the surface of a saucer mould. Thereby I could determine the temperature of the mould and the moist clay on it during the drying. The mould was put on a solid shelf in a chamber at a temperature of 80°, and it will be seen from Fig. 9 what happened.

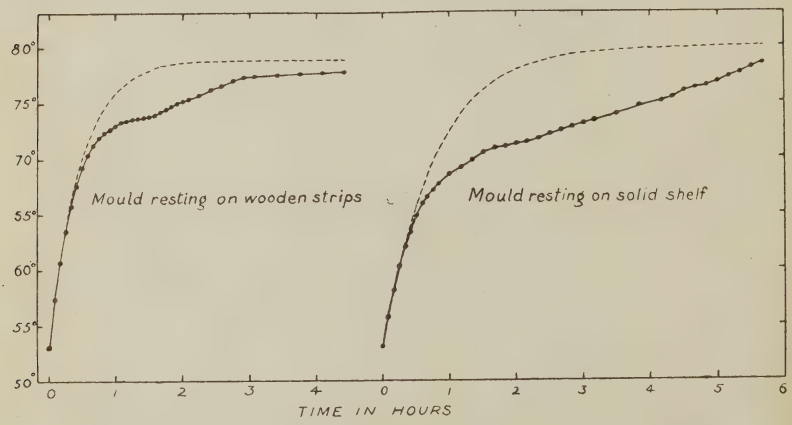


Fig. 9. Rate of warming of mould and fresh clay ware in still air at 79°—80°.

During the first half-hour, the temperature rose rapidly from 53° to 65°, but then it rose much more slowly, and it took about six hours before the temperature of the mould and ware rose nearly to the temperature of the chamber. The reason was that a very large amount of heat was being utilised to evaporate moisture from the clay, and if the clay had been dry from the first, the rate at which it warmed up is that indicated by the dotted line curve. In the other experiment portrayed, the mould was allowed to rest on two 2-inch strips of wood, with a 2-inch gap between them, and this caused the warming to be much more rapid; but it will be seen that at one point the mould kept at an almost steady temperature for nearly an hour, owing to the rapid evaporation of moisture from the ware.

It appears, therefore, that the ware requires a very long time to take up the temperature of the stove, especially if the mould is put on a solid shelf, as is usually the case in my experience, and it is evident that the hotter the stove the quicker the moisture will be driven off and the temperature will rise.

I made a number of experiments on the effects of air currents on the rate of warming of the mould (see Report for details). They indicated that the effect of the currents is more important than meteorological observations would lead us to imagine ; but they would cause only the 20 per cent. rise in drying rate already mentioned.

Weighing Experiments. A number of experiments were made in which samples of 7 and 8-inch plates were weighed before and after drying. The drying was effected in the large draw-out stove previously described, and I was able to vary the velocity of the air currents in the stove to some extent, by opening or shutting the wooden flaps at the bottom, and by blocking up some of the leak holes at the top. Samples of 8-inch plates, when dried for 8 hours in air at a velocity of 8, 10 and 15 ft. per min., lost 11·2, 12·6 and 14·6 per cent, respectively, of their moisture, but part of this loss, and perhaps most of it, was due to the fact that the drying power of the air (the difference between its wet and dry bulb temperatures) was 25·3, 26·4 and 27·7 in the respective experiments. Samples of 7-inch plates, when dried for 8 hours in an air current with a velocity of 10 ft. per min., lost 17·8, 18·1, 18·6 and 21·1 per cent of their moisture, the temperature of the air being 92·0°, 98·6°, 98·3° and 103·2° in the respective experiments, and its drying power being 21·7, 26·9, 26·9 and 28·5. That is to say, the loss of moisture varied considerably with the drying power alone, for the air currents were the same. Numerous other experiments showed the effect on drying produced by the drying power of the air, but the experiments were admittedly incomplete. Adequate experiments can only be made in a properly-equipped, technological laboratory.

Taking the evidence as a whole, I think it is sufficient to indicate that the working potters are right in their contention that, for the drying of moderate-sized articles and of moulds, high temperature is the important requisite. It is obvious that a certain amount of ventilation is essential ; but so far as the drying of ware is concerned, most of the stoves investigated had sufficient leak holes to ensure a fair ventilation even if they had no structural ventilators whatever.

On dividing up the observations into two groups according as they were made on well-ventilated stoves and on stoves with little or no structural ventilation, I found that the degree of saturation of the back draught air was almost the same in both groups. The higher the temperature the less saturated the air, for back draught air at 105°, 90° and 80° was found to be respectively 30,

39 and 48 per cent. saturated when issuing from well ventilated stoves, and 26, 38 and 52 per cent. saturated when issuing from the other stoves. It appears that the potters' stoves ventilate themselves, for the steam pipes on the floor heat the air in their neighbourhood, and this air, rising by virtue of its lightness, automatically induces a fairly rapid circulation. The chief question at issue, therefore, is the amount and destination of these currents of heated air. Every attempt ought to be made to direct them to the air outside, and to prevent their passing back into the shops, but it must be realised that if the prevention is successful, it will be necessary to instal an independent system of heating in the shops.

DISCUSSION.

THE CHAIRMAN (MR. T. BATES):—I do not intend to offer any practical remarks on the subject so well brought before you by Dr. Vernon. But the subject is one that requires considerable attention by every manufacturer. I suppose that the stoves which Dr. Vernon has investigated are stoves that are in existence in modern factories, because when you come to some of the stoves in the older factories you have difficulties that the lecturer does not seem to have touched upon this evening. But I am sure of this: we shall study the facts he has laid before us more carefully and in detail when we see the lecture printed in the "TRANSACTIONS." We may then arrive at conclusions as to the accuracy of the statements that have been made by the doctor, to whom we are all deeply indebted for his address. He will, no doubt, be very glad if you will question him on some of the statements he has made, or offer additional suggestions.

MR. A. LEESE:—The lecture has been a very interesting one, especially as it is a big problem that we are up against when we set out to produce a drying stove which shall give us sufficient heat to dry our ware and yet not be too hot to keep the workshops healthy. I think that, too often, one of the difficulties is that we have our stoves too near to the workmen. Another point that occurs to me is that if the stoves were built of concrete or some other material that is impervious to heat, this would be a great advantage. Most of our stoves are so jerry-built that the heat from the inside spreads outwards and gets into the workshops. The workpeople are, I think, often to blame to a great extent for the trouble that they meet with, inasmuch as they act contrary to what they are told is to their benefit, as well as better for the ware. I am afraid that the lecture to-night has been a little too deep for us to assimilate. It might be well for us to have an opportunity of looking into the facts and figures which Dr. Vernon has presented to us and discuss them at some of our later meetings. It should be a distinct advantage for us to study what we are each to do at each individual works with our varying kinds of stoves.

MR. A. FIELDING :—I would like to ask Dr. Vernon whether, in the course of his investigations, he came across any stoves in which the inside heat was not coming out through the top of the door as shown on one of the diagrams presented ?

DR. VERNON :—I found that stoves heated by the old-fashioned coke-burning stove pots were fairly efficient in preventing back-draught, and did not allow any outflow of hot air, provided that the doors were only open a few inches.

MR. FIELDING :—What would be the effect on a cold day if no heat were allowed to come out of the stove doors ?

DR. VERNON :—It would be necessary to instal an independent system of heating for the workshop.

MR. FIELDING :—Therefore, it would be rather detrimental to the workers if the stoves were made so efficient that no heat could come out at the top ?

DR. VERNON :—It would be the duty of the employers to have a proper heating system installed in the shops.

MR. FIELDING :—You could not rely upon the radiation to heat shops if the drying stoves were made as efficient as you would like to see them ?

DR. VERNON :—No. You would need an independent system of heating for the workshops.

MR. FIELDING :—Has Dr. Vernon actually come across a stove which has really satisfied his ideas of efficiency, together with an independent system of heating the shop ?

DR. VERNON :—Only in one instance, and unfortunately the independent system of heating was not working at the time I saw it.

MR. FIELDING :—Do you attribute the bad ventilation of the shops to the heat that comes out of the drying stoves ?

DR. VERNON :—I have no objection to heat coming out to such an extent that it does not act injuriously on the workers during a hot summer day, for instance. If you could keep the back-draught down to a limited extent, I do not think it would be harmful. But there are so many cases in which there is such a large amount of this backdraught that the shops get greatly over-heated.

MR. FIELDING :—You don't object to the humidity ?

DR. VERNON :—No ; I do not mind the humidity a bit. I think there are erroneous ideas abroad about humidity. There is such a lot of air coming through the shops that the moisture from the stoves and the moist clay does not, to any appreciable extent, raise the relative humidity of the air.

MR. FIELDING :—I asked that question because I have seen people go into potters' shops and hold a taper to the top of the stove doors. If there has been over so little draught the stove has

been condemned, and it has been said that provision must be made to prevent that.

DR. VERNON :—I have not yet seen a stove in which that has not happened, excepting the two cases which I have mentioned in my report.

MR. FIELDING :—I am very glad to hear the lecturer say that

MR. A. LEESE :—I think the best stove that I have seen was the one that was in operation at the works of John Edwards, Fenton—now Dennis'. I believe the same stove is still in existence. It consists of a long, wide chamber with internal corridors formed of shelves running crosswise, with doors for entrance from each of the benches. The latter run lengthwise on either side of the range, and at the far end, there is a set of steam pipes and at the other end a fan. Sufficient moulds are provided for each operator to work all day without any heat being applied. At night time the stove is closed up and the steam turned on into the pipes. The heat is then drawn through the stove by the fan, and by the next morning all the ware is dry, ready to begin again.

DR. VERNON :—Was no drying at all done during the day-time ?

MR. LEESE :—No ; none at all. Of course, at many of the existing works in the Potteries it would be quite a big job to reconstruct the premises so as to instal such stoves. What you want to do, is to set up entirely new buildings. I am certain, however, that much could be done in this direction, both to accelerate the drying and to improve the quality of the ware, as well as to ensure the healthiest conditions for the workers.

MR. E. A. R. WERNER :—I do not think it necessary for me, in moving a vote of thanks to Dr. Vernon, to go into details, but I would commend to your very close attention the behaviour of those convection currents that travel round the stove and the shop outside as one circuit, which Dr. Vernon has so ably described, and which explain the great difficulty of removing hot moist air by ventilators, whether natural or fan-aided, because the air is continually travelling in this orbit and is consequently heated up in its passage through the stove. Does not this suggest that there is urgent need for experiments in the direction of utilising pre-heated air—air which has already been heated up to a determined extent—before it is passed into the stoves, and will it not be along these lines that you will ensure better drying, greater thermal efficiency, and greater control over the temperature and humidity conditions of the air, whilst at the same time preventing unintentional and accidental interference with the air of the potters' shops outside the stoves ? Dr. Mellor has told you that he likes a room hot, and I think that is pretty true of the Potteries generally. But can we not find reasons why the potters deliberately prefer to have their shops 5 or 7 degrees hotter than the workers in a fuse shop ? Dr.

Mellor has pointed out one reason for a preference for closed windows, viz. :—the avoidance of speckled ware through dust and dirt lodging upon it during the making. But I venture to believe that a great many of my friends in this district would still prefer the higher temperature even if the air that came in from outside were perfectly pure and clean.

My friend, Dr. Vernon, knows that I have been for a long time seeking a possible reason for this preference, and it has occurred to me that it might have some connection with the constant handling of wet clay, since the latter must to some extent extract heat from the body ; hence the potter's preference for additional warmth. But are we not wandering in a circle ? Dr. Vernon has told us that the relative humidity of the hot air that comes out into the potters' shop and the resulting warm air in the potters' shops is no greater than that of a considerably cooler engineering shop. That may be so, but if, by the opening of a window or other means, the temperature in a potter's shop is suddenly reduced say 10 degrees, surely one ought to get the air considerably nearer saturation point, and in that case it will become distinctly unpleasant, since it will then be relatively very humid air, and to avoid that the workers prefer to keep the shop hot. The moral arising from this, surely, is to improve the efficiency of the ventilation of the potters' stoves in order that this large amount of total moisture shall not pass from the stoves into the shops ; in which case there would, I think, be no need to keep the temperatures unduly high to avoid this excessive relative humidity.

I should like to ask the lecturer to clear up a difficulty which I find at the top of page 57 of his report—I have not the slightest doubt that there is a simple explanation of it—where Dr. Vernon goes into the question of the drying power of one volume of air heated from 60 to 100 degrees as compared with 4 volumes heated from 60 to 70 degrees ; and again in the fourth column of the table in the middle of that page where, in connection with the drying power due to temperature, we get 10 for 100 and 2·4 for 70. Are not these the drying powers of equal volumes of air ? Just as the velocity of the air currents goes up from 10 to 40, will not the mass factor have to come in and give us against the 10, four times 2·4 ?

I must apologise if I have digressed, but I feel it a great honour and privilege to be amongst you to-night and to have the distinction of acting as your spokesman in moving a very hearty vote of thanks to the lecturer.

Major B. J. Moore :—In seconding this vote of thanks to Dr. Vernon, I would like to make one or two remarks on small points that I have noted during the course of the lecture. These I cannot help coupling with the remarks of Mr. Werner, because I think in a way that people generally outside the district are prone to be rather too dogmatic in laying down rules for a given industry. I feel myself that one cannot lay down hard and fast rules regarding

the drying of poters' ware, because the conditions that will suit the drying of china will not necessarily suit the drying of domestic earthenware or sanitary ware, or *vice versa*. If I correctly understood Mr. Werner to say that adequate ventilation in potters' stoves should consist of getting rid of the moisture as quickly as possible, I would say that, under these conditions, we should have endless trouble with certain kinds of ware in the direction of cracking, scumming and other faults. Some time ago I went so far as to make a stove for the drying of china plates in which the heating-up was done by means of blowing hot air into the stove. I thought this stove would be thoroughly efficient, but I only had four plates good out of 14 dozen in one particular drying. In the course of further experiments I cut down that super-heated, dry air until, at the present time we are putting in none at all. My own opinion is that plates require not a dry atmosphere, but a somewhat damp one, to enable them to dry evenly. By blowing air into a potter's stove you create currents which, though they may be quite satisfactory in the case of some kinds of ware, will not suit others. I think one of the most important points that Dr. Vernon's remarks have brought forward from a potter's standpoint, is that, at the present time, we are really ventilating our stoves *too well*. In other words, we are wasting heat, because I think his figures prove that the air leaving our stoves is not by any means saturated. Surely it is up to us to get all the benefit we can out of the heat that is available, because it has cost money to produce. At the same time, I think, that what we should aim at doing, is to make our stoves ventilate more to the outside atmosphere and less into the workshops themselves. By all means give them less ventilation, but what ventilation occurs, let it go to the outside and not into the interior of the potters' shops.

One of the reasons why the potter likes a higher temperature than other workers is, no doubt, that he is working in extremes of temperature. He goes up to a stove that is approximately 100 degs. F., and if he goes back from that to work in a normal temperature—say 63 degs., or thereabouts—he feels the change of temperature too much. I think that is probably one of the principal reasons why the potter likes this higher shop temperature.

I have very great pleasure in seconding the vote of thanks to Dr. Vernon for his address.

DR. VERNON:—In reply to Mr. Werner's question about the drying power of one volume of air heated from 60° to 100° as compared with that of four volumes of air heated from 60° to 70°, these comparisons are not for equal volumes of air, as he suggests, but for the total quantity of air passing in a given time. If air passes over an object at a rate of 40 ft. per minute, it is clear that the actual volume of moving (and drying) air is four times greater than if it passes over at the rate of 10 ft. per minute.

I quite agree with everything Mr. Werner said with regard to

the preheating of the air. I am sure the potters could do a good deal more for themselves than they do at present by taking simple precautions. In Major Moore's own stove, I remember that directly I opened the bottom flaps of the stove the air went between the steam pipes, instead of over them, and thereby picked up more heat.

As regards the fact of moist clay being found cold to the hands, this is, of course, the case ; but in engineering shops the metal is generally cut in cold soapy water, and therefore the arms of the workers get quite as cold.

With regard to the opening of the windows reducing the temperature of the shop, and thereby causing the humidity of the air to be increased from 60 to 70 per cent. Obviously, if you open the windows and get the air through the shop at a greater rate than before, you remove this humidity. You have a certain percentage humidity in the air at 70 degrees, and if you cool it down from 70° to 60°, then the humidity is counteracted by the increased air currents carrying the moisture away.

As regards getting rid of moisture, I shall not attempt to tackle this question. I am only keen on preventing this backdraught air from getting into the workshops, and thereby creating such conditions as are not good for the workers. Most of the stoves that I saw were really over-ventilated.

With regard to the humidity, I have a host of figures (See p. 69 of my Report) which show that the hotter the air becomes, the less it is saturated with moisture. If you were to reduce the air currents, I think you would still have air that is quite dry enough in your stoves—dry enough, at all events, for your particular purposes.

VIII.—A Study of Factors Involved in Slip-Casting.

By S. R. Hind, B.Sc., A.R.C.S., A.I.C.

INTRODUCTORY.

THE following work was all done with sanitary earthenware slip, sampled as occasion required from lots of several tons actually in use in the factory.

Casting slip is very subject to variations, from time to time, of an apparently inexplicable nature, and a little preliminary study shows that the factors involved are very numerous. Until these are properly and *quantitatively* understood and can be allowed for, control must be a very haphazard and not very successful enterprise. This work is of a purely introductory nature, having as its purpose the elimination of as many unknown variable factors as possible, so that eventually it may be possible to measure quantitatively and in a way that can be directly applied to practice, the effect of variations and alterations in the body itself. It must also be pointed out that the following studies only represent one point of attack upon the great subject of the control and behaviour of casting slip, and it is hoped that eventually the numerical "constants" here obtained will link up with others obtained by attacking the subject from other points of view. Though the deductions are in some respects open to question and in others elementary and incomplete, it is hoped that they will contribute to a clearer understanding of the subject.

THEORY AND METHODS.

The theory here given is the result of a process of cross-checking of my own ideas on the subject against experimental evidence. Numerous other points of view have appealed to me from time to time, but the one given here is the only one that has stood the test of experiment, with, I think, reasonable success. Roughly speaking, the following factors are recognised as influencing slip-casting:—

(1) Time required for casting-slip in a plaster mould to give the required thickness of solid casting.

(2) Alteration, if any, of the slip during casting. For example, it is conceivable that the slip poured off from the mould has a less proportion of water (higher slop weight) than that originally used.

(3) The proportion of water in the original slip.

(4) The proportion of water in the cast clay on the mould.

(5) The porosity of the mould.

(6) The degree of saturation of the mould.

(7) The temperature at which casting takes place (not studied in detail).

(8) The viscosity and "stickiness" of the casting-slip.

(9) The resistance of the cast clay to the passage of the water.

The following methods were employed to get as accurate figures as possible.

Time. Owing to the considerable viscosity and a certain tendency to gelatinization of the slip on standing, a notable amount of the slip remained on the casting after pouring off. This continued to cast up. After a while the shiny wet surface assumed a matt appearance due to the disappearance of superfluous water and the time when this occurred was noted in the later experiments. As the amount left behind in the trials with the same slip under similar conditions is practically constant, it can be allowed for in the calculations, but the corroborative evidence obtained by timing both to "running off" and to "dry surface" is valuable.

Moulds. The moulds used consisted of plaster slabs each having a central rectangular depression approximately 12 cm. by 7·5 cm. by 2 cm. deep with the corners rounded off. The thickness of the plaster was 1" all round the depression, with the bottom increased to 2" and 3" in certain moulds. Batches of moulds "hard," "ordinary," and "soft" were made by the mould-makers, and they proved to have porosities corresponding to the figures given below.

	Gms. Water Absorbed by 100 Gms. Plaster.
Hard	31
Medium	44
Soft	52

Slop weight. The slip was weighed in a small calibrated glass bottle of approximately 100 cc. capacity. The slop weights so measured, could be relied upon to about 0·02 oz. per pint as a maximum error. Knowing the mean density of the dry earthenware body the proportion of water in the slip follows from the slop weight.

Proportion of water in Cast Piece. As soon as the casting exhibited a "dry" surface it was removed from the mould on to a tile and a piece 38·75 sq. cm. in area cut out by means of a metal cutter, slightly greased with vaseline. The piece cut out was slipped on to a tared filter-paper, weighed, dried at 105°C and reweighed.

Saturation of Mould. The moulds were air-dried. (The

experimental results cast some doubt on the completeness of the drying, but more drastic methods could not be safely employed owing to the nature of the plaster). To the mould was added a measured quantity of water corresponding to the degree of saturation required and this was allowed to disappear into the plaster. Only a few minutes were then allowed before the slip was poured into the mould. In future work of this nature it would be advisable to allow about an hour for the water to distribute itself evenly through the plaster, but unfortunately this was not realised at the time of the experiments.

Viscosity of the slip. This only affected the time of casting and so was allowed for without being directly measured.

Resistance of Cast Clay. This was usually deduced from the formula developed hereafter, but a check on the figures obtained is described later.

Thickness of Casting. This was at first measured by eye against a millimeter steel scale, and was afterwards also worked out from the figures relating to the piece cut out by the die. Owing to slight variations in thickness of the cast piece, the significance of the figures obtained by the second method is not much greater than by the first, rough method.

Slop weight of Slip Run off from Casting. This has been frequently measured and is always the same as that of the slip originally put into the mould. The term "clay" is for convenience, applied to the earthenware body as a whole.

The following deductions are based on the assumptions:—(*a*) That the plaster is, throughout casting, exerting a constant pull on the water in the slip; (*b*) That the clay is laid down on the plaster in a perfectly uniform manner, those portions cast earlier not being different in composition and arrangement of their particles from those subsequently deposited.

These conditions are fairly well observed in casting, with the exception of solid casting to great thickness over very long time, when the increased degree of saturation of the mould becomes a serious factor.

Let the rate at which water passes through a square cm. area, 1 cm. deep, of clay on a given plaster mould$=x$ cc. per cm^3 per hour; let the thickness of casting attained after a given time t hours$=l$ cm.; let the ratio of Volume of solids: Volume of liquid in the slip be r_2; the ratio—Vol. of solids: Vol. of liquid in the cast clay be r_1; and ratio of the Volume of cast piece: Volume of water removed be r_0; Then it follows that

$$r_0 = \frac{r_2(1 + r_1)}{r_1 - r_2}$$

Now let us consider the state of affairs at a time t from commencing casting, when a thickness l cm. of clay has been attained. In the subsequent small period of time δt, let an additional small thickness δl cast up.

Then on an area of 1 sq. cm. the water liberated and passed to the mould amounts to $\delta l \times \left(\frac{1}{r_0}\right)$ cc., and the momentary rate of removal of the water is—

$$\frac{\delta l}{\delta t} \cdot \frac{1}{r_0} \text{ cc. per hour.}$$

Making the period of time infinitely small, this reduces to

$$\frac{dl}{dt} \cdot \frac{1}{r_0}.$$

But the rate of removal of the water $= x$ cc. per cm^3 per hour, which is equivalent to $\frac{x}{l}$ c.c. per 1 cm. thickness on a sq. cm. area per hour

therefore $\frac{dl}{dt} \cdot \frac{1}{r_0} = \frac{x}{l}$, which integrated becomes $l^2 = 2x\, r_0\, t$,

or expressing l in terms of millimetres, $l^2 = 200x\, r_0\, t$.

Calculation of l from the dry and wet weights of a known area of casting. Where a series of observations with the same slip is under consideration, it usually happens that r_1 is a constant, in which case l is readily calculated in terms of the mean r_1 and W_c the dry weight of the piece cut out.

It follows then that $l = \left(\frac{10}{A \times \rho} \times \frac{1 + r_1}{r_1}\right) W_c$ mm.

in which the bracketed portion is a constant for the series, A is the area of piece cut out and ρ the density of dry material.

The above formula requires the pores of the casting to be entirely filled with water at the moment when the "dry" surface appears, which is the case.

Effect of Degree of Saturation of Plaster Mould. No theory has been arrived at which will give a rigid expression for this, but the following considerations put the matter in a form in which experiment can easily be brought to bear upon it.

The following observations have to be borne in mind:—When water is poured into a dry plaster mould, and allowed to sink in, and the mould broken across it is seen that the water has saturated the plaster concentrically from the wetted face. But, on standing for half an hour, the sharp edge of the wet region has disappeared and after a couple of hours the water has so distributed itself that the whole of the plaster appears to be uniformly moist. This probably means that the water has retreated into the finer pores and crevices between the crystals of the plaster, leaving only the larger pores empty.

Now let us consider the general state of affairs in casting on a surface of 1 sq. cm.; (in this the "head" was 1 cm.)

Let F = The "pull" or surface-tension force causing water to flow into the plaster.

Let R_p = Viscous resistance to flow of water in the interior of the plaster.

Let R_c = Viscous resistance to flow of water through the cast clay on the mould.

Then $F = R_p + R_c$

But comparison of experimental figures shows that R_p is negligably small compared with R_c, being in the present case of the order of $\frac{1}{100}$ of the latter resistance. Consequently we may take as a close approximation that $F = R_c$

Now $R_c = \frac{8lV\eta}{\pi r_c^4}$ where η = viscosity of water

V = volume of water passing through 1 cm² per hour

But $V = \frac{x}{l}$

r_c = a suitable mean radius for the pores of the casting, for this purpose assumed to be circular cylindrical.

therefore $R_c = \frac{8\eta}{\pi r_c^4} \cdot x$

Considering a dry plaster, we may take its absorption force to be equivalent to that of a certain number of circular, cylindrical pores of a certain size, perpendicular to the casting-face and running from side to side of the mould, in which case

$F = n_p \cdot \frac{2\sigma}{r_p}$ where n_p = No. of pores per cm.² of plaster.

r_p = radius of mean pore

σ = surface tension of water

But as the plaster becomes saturated the pores fill up with water, those smallest and therefore exercising the relatively greatest pulling force on the water, filling first, so that at a degree of saturation represented by s (the ratio of water in the mould to that required for complete saturation) the number of pores free to exercise a "pull" on the water $= n_p f(s)$ where $f(s)$ is some mathematical function of s depending on the size-ranging of the pores.

Then in general, $F = n_p \cdot \frac{2\sigma}{r_p} \cdot f(s)$.

therefore $x \cdot \pi \frac{8\eta}{r_c^4} = n_p \cdot \frac{2\sigma}{r_p} \cdot f(s)$.

Now let x_o be the value of x when $s = 0$

Then it follows that $x = x_o f(s)$. for any particular slip and combining this with the thickness-time formula

$$l^2 = 200 x_o r_o t. f(s).$$

Now in a series of experiments in which the only independent variant is s, if l_w and l_d are the thicknesses of the castings on wet plaster and on dry, we get

$\frac{l_w^2}{l_d^2} = f(s)$, from which the value of $f(s)$ should be determinate.

EXPERIMENTAL.

The effect of temperature was not studied in detail, the slip being used at the temperature at which it was drawn from the slip supply pipes. This varied from 10°C to 20°C.

The experiments were undertaken to establish the formula by the following stages:—

A. Relation between l and t, other things being, as far as possible, constant.

B. Relation between $\frac{l^2}{t}$ and r_0 (derived from slop weight of slip and moisture in casting).

C. Relation between l and s.

C. divides into the sub-groups:—

(*a*) Relation between l and percentage of water in a series of moulds of same blending.

(*b*) Relation between l and thickness of different moulds of similar blending (1″, 2″, 3″).

(*c*) Relation between l, percentage of water in plaster and porosity of the plaster.

A. Relation between l and t. In the accompanying graphs for series 1, 2, 3, and 18, the measured thickness of the casting in mm. is plotted against the square root of the time in hours. The probable experimental error of 0·1 mm. is shown by the circle surrounding each point.

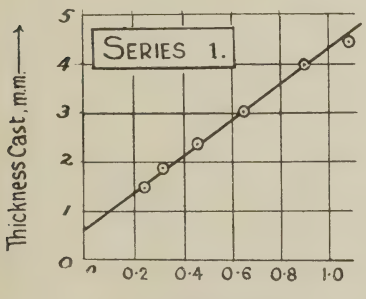


Fig. 1.

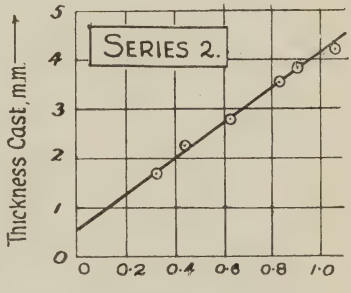


Fig. 2.

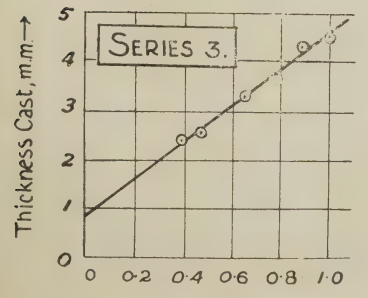


Fig. 3.

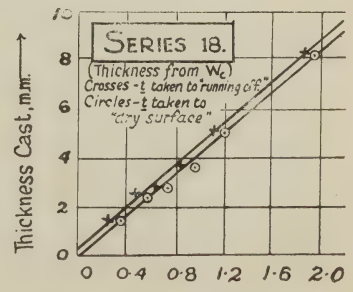


Fig. 4.

Series 18 was done two years later than series 1, 2, 3, on the same moulds, which had received a varied treatment in the mean time and showed signs of age. The slip used in series 18 ran off more fluid and gave a casting of a more dense and "short" nature than the earlier slip. The series was undertaken to demonstrate that the correction applied to l in the former series is due to the casting up of slip retained on pouring off.

Several other series were done with similar results.

The laws corresponding to the graphs are as follows:—

Series No.	Law of Graphs	l^2 Law
1.	$l-0{\cdot}70=3{\cdot}63\sqrt{t}$	$(l-0{\cdot}70)^2=13{\cdot}2\ t$.
2.	$l-0{\cdot}70=3{\cdot}36\sqrt{t}$	$(l-0{\cdot}70)^2=11{\cdot}2\ t$.
3.	$l-0{\cdot}92=3{\cdot}64\sqrt{t}$	$(l-0{\cdot}92)^2=13{\cdot}3\ t$.
18	$l-0{\cdot}33=4{\cdot}25\sqrt{t}$	$(l-0{\cdot}33)^2=19{\cdot}1\ t$.
	$l\quad\ =4{\cdot}25\sqrt{t}$	$l^2\quad\ =19{\cdot}1\ t$.

It may thus be taken as proved that, with a given slip at constant temperature the rate of casting is expressed by $l^2=at$, where a is constant, due allowance being made for the fact that on running off, a notable amount of slip remains on the casting.

B. Relation between $\frac{l^2}{t}$ *and* r_o.

Casting-slip at 36 to 37 oz. per pint was taken and diluted down in portions by approximately 1 oz. steps to 32 oz. per pint and two parallel castings done with each slip. All the castings were done either over the same period of time from filling to running off, or cast one half hour, and one one hour for each slop weight.

The results are complicated at the lower slop weights by a distinct change in the nature of the casting which becomes harder and more brittle and casts up with a gritty surface.

A more subtle change takes place at the higher slop weights, accompanied by a slight increase in the proportion of water in the casting. This seems to be a structural alteration in the agregation of the solid particles which results in a regular alteration of the rate at which water can pass through the casting.

Putting the simple formula into the form $\frac{l^2}{t}=200x.\ r_o$ the experimental evidence (see later) leads one to the alternatives:

(1.) The thickness cast in a given time is *not* connected with r_o, the proportion of volume cast to water released.

(2.) The thickness cast in a given time *is* proportional to r_o, but x, the velocity of flow of water is not necessarily the same for castings from slips of different slop weights (but the same origin), owing to the arrangement of the particles of the casting altering.

The logical necessity of r_0 being a factor, coupled with the observed alterations in the nature of the casting, make the alternative (2) the only one which will suitably fit the facts.

In the graphs, herewith, for series 19, 7 and 8, $\frac{l^2}{t}$ is plotted against r_0, the values also being given in the tables below.

SERIES 19.

Slop Weight Oz. per pint	r_2	r_1	r_0	$\frac{l^2}{t}$	$x = \frac{l^2}{200 r_0 t}$
37·33	1·136	1·90	4·31	17·9	0·021
37·33	1·136	1·86	4·50	17·5	0·020
36·19	0·977	1·86	3·14	11·6	0·019
35·52	0·899	1·84	2·71	10·5	0·019
35·30	0·876	1·85	2·57	9·87	0·019
33·90	0·736	2·12	1·66	12·5	0·038

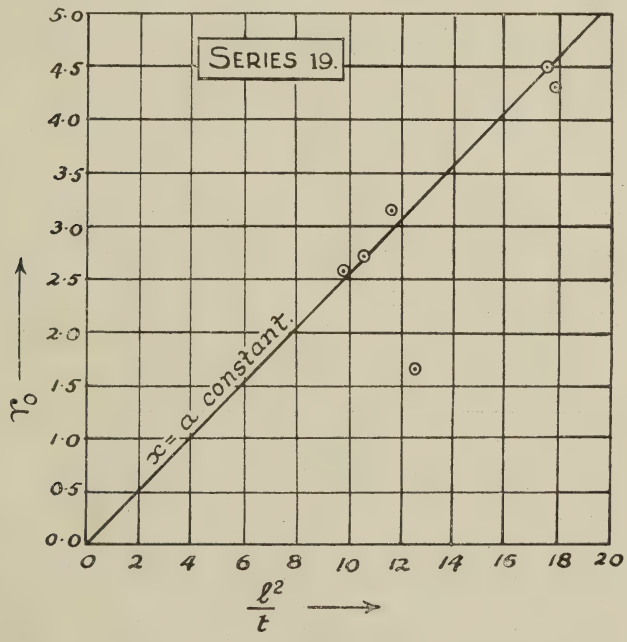


Fig. 5.

As the variations in x at very low slop weights far out-weigh those in r_1, the following earlier series are given to corroborate series 19, r_1 was taken as 1·90 throughout, which was the normal figure with the actual casting-slip in use at the time when series 7 and 8 were carried out.

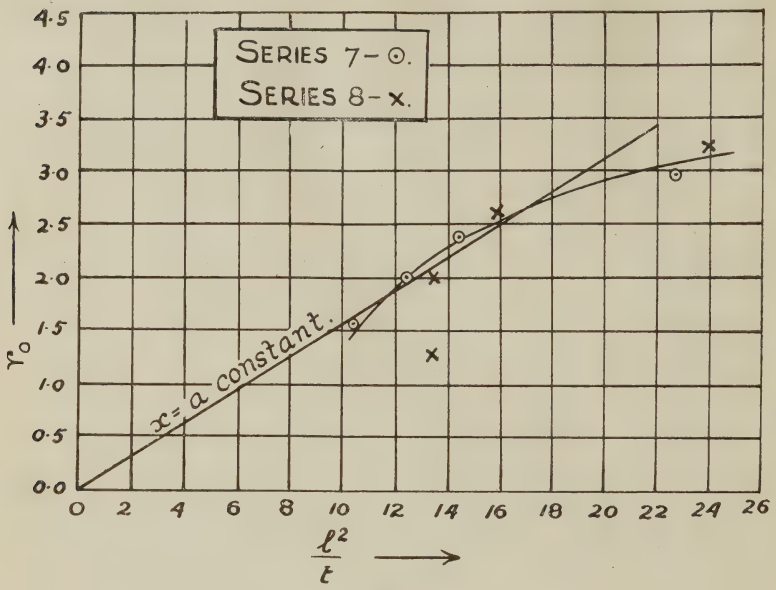


Fig. 6.

SERIES 7.

Slop Weight oz. per pint	r_0	mean $\frac{l^2}{t}$ *	Mean x.
36·0	2·98	22·8	0·038
35·0	2·36	14·5	0·031
34·0	2·00	12·5	0·031
33·0	1·56	10·5	0·034

SERIES 8

Slop weight Oz. per pint	r_2	r_0	Mean $\frac{l^2}{t}$	Mean x.
36·38	0·998	3·22	24	0·037
35·5	0·897	2·60	16	0·031
34·0	0·752	2·00	13·5	0·034
33·0	0·663	1·56	10·8	0·035
33·0	0·582	1·28	13·5	0·053

Corrections for l were 0·3 mm. at 36·38, 0·2 at 35·5 oz. per pint and negligible at lower slop weights.

* l had to be corrected for slip remaining after running off. This was equivalent to 0·68 mm. at 35 and negligable at 34 and 33 oz. per pint.

The relation of x to other factors such as r_0 and r_1 was not studied, but should be at some later date.

It is sufficient for the present, that in the region of thin, but not "watery" casting slips the value of x is sensibly constant, (but see also Fig.6) when the thickness cast in a given time from the different slips of the same series is taken as depending on r_0 according to the relation, $\frac{l^2}{t.r_0} = 200x$. These conclusions are strengthened by the general similarity to one another of castings within these limits and their more or less marked dissimilarity (in "feel" and r_1) from castings derived from slips outside this range, particularly below it.

Sundry values of x determined at other times with ordinary slip are as follows:—
0·031; 0·027; 0·033; 0·018 (two months later than previous three); 0·017; 0·022; 0·020. The lower figures correspond to a slip giving a "shorter" casting.

We will take it, then, that $l^2 = 200x\ r_0\ t$.

Rate of Passage of Water through Clay Casting. The values of x calculated from the formula were checked experimentally as follows: An ordinary air-dried medium plaster mould, one inch thick was used. The slip was cast up for half an hour in the usual way, run off and a small funnel of known end-area pressed into the cast clay and clay pressed round to make the edges water-tight. The funnel was quickly filled up with distilled water to a mark on the funnel. Every five minutes water was run in from a burette to make up to the mark, to compensate for the water which had passed through the cast clay into the mould.

The rate of passage of water was practically constant at $x=0{\cdot}0212$ cc. per cm^3. per hour for the first hour, after which it decreased at a rate greater than could correspond to the increasing saturation of the plaster mould.

It was not found possible to get a value of x at the same time, by way of the l^2 formula, but it is clear that the above value is of the same order as the calculated values on similar slips.

C. Relation between l and s. (*a*) Relation between l and percentage of water in a series of moulds of the same blending. See graphs appended for series 12, 13, 14, 15, (Figs. 7, 8, 9, 10) where in each case, the percentage of water added to the mould (by weight) is plotted against the dry weight of the cut-out piece of casting. In such series the time of casting was as nearly as possible the same throughout. It is notable that in each series the thickness obtained on the *dry* mould does not conform with the rest of the series, giving a higher value than would be expected from the trend of the other figures.

To keep the calculations as simple as possible subsequently, the zero point conformable with the rest of the series is taken as that point at which the curve produced cuts the abscissa for Moisture in Mould=P%=*O*. With reasonable care, the accuracy

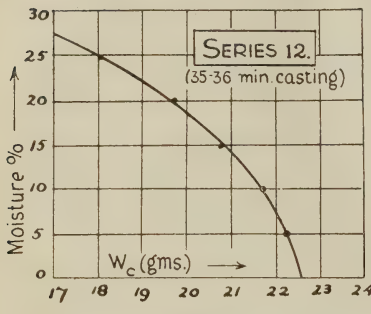


Fig. 7.

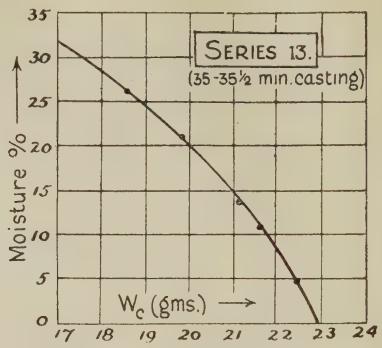


Fig. 8.

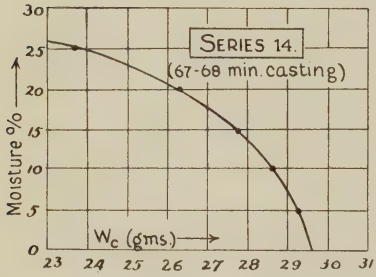


Fig. 9.

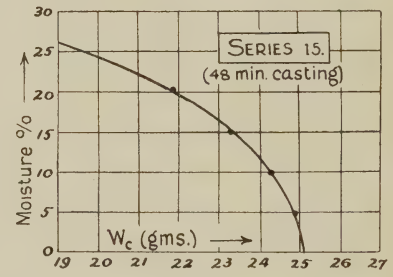


Fig. 10.

of this precedure is of a similar magnitude to the experimental error.

Now in any series of experiments having t, r_0, x_0, constant, it follows (p. 94) that

$l^2 = a\,f(s)$ where a is constant; $f(s)$ is some function of the degree of saturation of the plaster mould.

The figures here given graphically for series 12 to 15 have been found to agree best with the hypothesis $f(s) = 1 - s^2$

i.e., $l^2 = c\,(1 - s^2)$, where c is a constant.

Now if l_w = thickness cast on mould of moisture, s.

l_d = thickness cast on dry mould $(= \sqrt{a}.)$

Then $1 - \dfrac{l_w^2}{l_d^2} = s^2 = f(P)$, say.

The law is tested, therefore, by evaluating $\sqrt{f(P)}$ from the various weights of casting in the series and plotting the results graphically against P, the percentage of water added to the mould. (See straight-line graphs for series 12 to 15.).

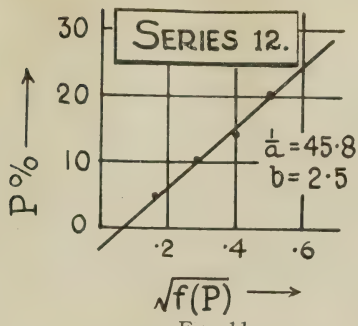


Fig. 11.

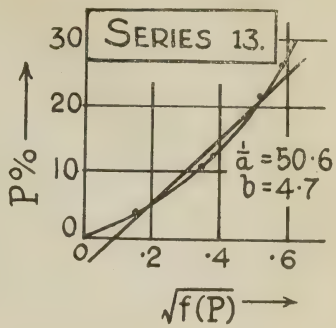


Fig. 12.

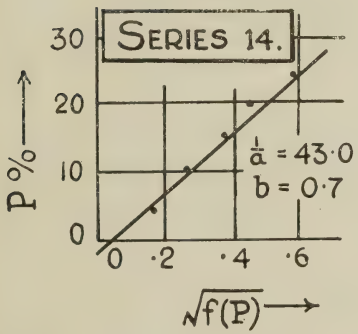


Fig. 13.

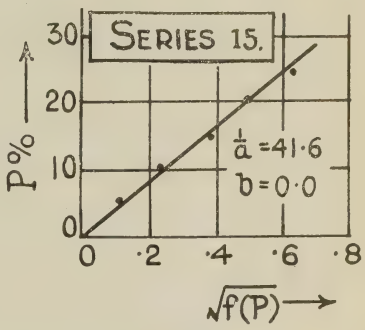


Fig. 14.

These graphs show that, within the limits set by the experimental error

$$\sqrt{f(P)} = \frac{1}{a} \cdot (P + b).$$

$\frac{1}{a}$ and b are interdependent as is shown by Fig. 16 and $\frac{1}{a}$ tends to 42% when $b = 0$.

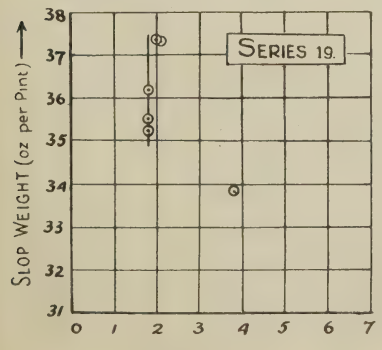


Fig. 15.

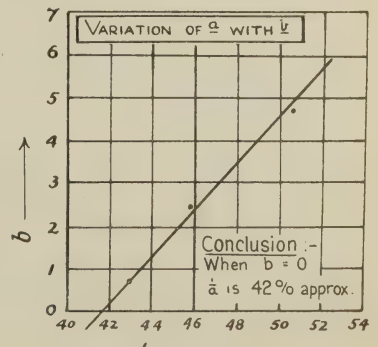


Fig. 16.

The variations of a and b from series to series are possibly due to either or both of the following causes :—

(I.) The air-dried moulds were rarely quite dry, on account of climatic conditions, all the six moulds used usually having this same amount of accidental moisture.

(II.) As the necessity for proper distribution throughout the plaster of the water (used for partial saturation of plaster) was not properly realised at the time of the experiments, the variations, from series to series may be caused by variations in the time allowed between adding the water to the mould and pouring in the casting slip.

Both suppositions lead to the adoption of a value of a corresponding to $b=o$ as being that applying under works conditions.

From this then

$$\sqrt{f(P)} = \frac{P}{42}$$

Now the porosity of the moulds used was 44%, so that if $l^2 = 200\ x\ r_0\ t\ (1 - S^2)$ we should have $\sqrt{f(P)} = \frac{P}{44}$ and the law can be considered proved within the limits of experimental error, as far as *medium* hard plaster, one inch thick, is concerned.

C. (*b*). Relation between l and Thickness of different Moulds of Similar Blending.

All medium-blended plaster, approximatley 1″, 2″, 3″ thick from casting-face.

W_c given below is proportional to l.

SERIES 16.

Moulds + 10% of water		Moulds + 25% of Water	
Thickness of plaster	W_c	Thickness of plaster	W_c
cm.	gm.	cm.	gm.
2·25	27·3	2·50	23·7
5·1	27·3	5·25	23·9
7·45	27·5	7·7	22·0

SERIES 17

Mould + 10% Water.		Mould+25% Water	
Thickness of Plaster	W_c	Thickness of Plaster	W_c
cm.	gm.	cm.	gm.
2·65	35·9	2·35	30·8
5·1	36·0	5·25	33·0
7·45	36·2	7·7	32·4

The variations are small and erratic, and it is concluded that the casting formula is independent of the thickness of the plaster, except in so far as this is involved in s, the degree of saturation of the plaster.

C.(*c*). Relation between l, percentage of water in plaster and porosity of the plaster.

The following show the porosities of the plaster used, in percentages of water absorbed, by weight: "Soft," 52%; "Medium," 44%; "Hard," 31%

The plaster was blended by a regular mouldmaker. It can readily be shown that, if $l^2 = 200\, x_0\, r_0\, t\, (1 - s^2)$ is only affected in s by variation of the blending (porosity) of the plaster, then

$$P = \sqrt{\frac{625W^2_{10} - 100W^2_{25}}{W^2_{10} - W^2_{25}}}$$

Where

P = Weight porosity of the mould.

W_{10}, W_{25} = Weights of clay pieces of equal area, cast, other things being equal, on moulds previously soaked with 10% and 25% of water on the weight of the dry mould. (W is proportional to l.)

This test was applied to figures obtained in series 16 and 17 with the results shown below:—

Blending of Plaster	Soft	Medium	Hard
Porosity observed .. %	52	44	31
Porosity calculated from Series 16 .. .. %	56	46	38
from Series 17 .. .. %	58	51·5	34
Mean for Series 16 and 17 %	57	49	36
Difference .. .. .. %	5	5	5

It is important to note that the plaster moulds used in these experiments were blended and made in a similar manner to moulds used for casting sanitary ware. Consequently, the formula here developed might require modification if the permeability of the plaster at any given porosity were greatly altered by special methods in making the moulds.

Thus, though the calculated and observed values do not coincide, there is, on the average, a constant difference, of comparatively small proportions.

It is concluded from the figures that the general casting formula may be taken as reasonably exact when the mould is not more than half-saturated. Thus, for a given normal casting-slip the thickness of the casting is given by:—

$$l^2 = 200\, x_0\, r_0\, t\, (1 - s^2), \quad \text{where}$$

l = thickness cast in mm., in time t hours; x_0 = the rate of passage of water through 1 cm. cube casting on to a dry mould in cc. per hour; r_0 = ratio of volume of casting: volume of water removed; s = ratio Water in mould: water required to saturate mould. For

the remainder of the range the agreement is not so close (This would not be of much importance in practice, as such moulds are not generally satisfactory in use).

Effect of Temperature of the Slip. As before stated (p. 91), this was not studied in detail, one series only was done to get a general idea of the effect.

SERIES 6.

Temperature	$\frac{l^2}{t} \propto x r_0$
15	12·5
20	12·0
25	9·7

The casting tends to become harder and "shorter" at the higher temperatures and softer and more plastic at the lower temperatures; so that it is likely that r_1 will be greater at high and less at low temperatures.

As regards the general effect of alterations on the nature (quality) of the casting it may be mentioned that: (*i.*) Less alkali in the slip; (*ii.*) Higher slop weight, and (*iii.*) Lower temperature, all seem to operate in the same direction, *i.e.*, to give a softer, more plastic and thicker casting.

This work was done in the laboratory of Messrs. Geo. Howson and Sons, Ltd., Hanley, to whom I owe my best thanks for the facilities they afforded me.

IX.—Notes on the Crystalline Structure of some China Clays examined by the X-ray Powder Method.*

By Sir William Bragg, F.R.S., G. Shearer and Dr. J. W. Mellor.

STATEMENT OF THE PROBLEM.

By J. W. Mellor, D.Sc.

THE problem as to what happens between about 500° and 1200° when clay is heated has not been solved. So far as the available evidence goes, the most simple assumption is that the kaolinite molecule $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ breaks down into free silica, free alumina, and water. This evidence has been fully described in back papers of the Transactions. There is further evidence that the free alumina polymerizes and possibly crystallizes at about 900° ; and that, at a higher temperature, the free silica and alumina recombine to form sillimanite. The evidence is purely circumstantial, and awaits an *experimentum crucis*. I wrote to Sir William Bragg, asking if he thought an X-ray examination of the calcined clay would throw any light on the subject, and in reply, he offered to make some trials. His observations are indicated below. The results have thrown some light on the subject, but have raised other questions which will have to be dealt with later on.

It appears from his observations : (i) that when the clay loses its water, it loses its internal crystalline structure, and gives no spectrum ; (ii) that a new crystalline substance appears when the clay is calcined at about 1000° ; and (iii) that sillimanite appears later on. The crystalline substance has not been identified ; it is not sillimanite. The reduction in the solubility and chemical activity, and the thermal phenomena which attend the change are so like those presented by alumina alone, that the conclusion to be drawn is that it is the free alumina, produced at about 500°, which is the cause of the phenomena. If the X-ray spectrum confirms this, the problem will be solved. This should not be difficult, and in the next report it is hoped that the "new substance" will have been identified.

* Published by permission of the British Refractories Research Association.

NOTES ON THE METHOD OF X-RAY ANALYSIS.

By Sir WILLIAM BRAGG.

When a fine pencil of X-rays of definite wave length passes through a thin layer of a powdered crystal and falls on a photographic plate a few centimetres behind the crystal layer, a series of concentric rings is impressed on the plate in addition to the relatively very bright spot due to the direct rays. These are diffraction rings; but they differ essentially from the ordinary visible diffraction rings, which may be formed with light rays under various circumstances. The different rings do not, as in the latter case, denote different wave lengths in the incident radiation; there is, in fact, only one wave length. They each denote some spacing between consecutive planes of atoms in the crystal. Every crystal has its own characteristic spacings, and, therefore, its own characteristic spectrum, and no two crystals are entirely alike. Consequently, the X-rays afford a method of identifying anything of a crystal nature in a powdered material.

If the powdered material contains more than one kind of crystal, the experiment shows two sets of rings. The rings due to each crystal are sharply defined, as if no other were present. When the crystals are exceedingly small, each containing a few atoms only, the rings become broader and more diffuse.

The main difference between this analysis and the analysis of the chemist is that the former shows the state of combination of the material; the latter the atoms which are combined. Each has, therefore, its own field.

In practice, it is convenient to use a fine slit, say half a millimetre wide and a centimetre long, in order to define the X-ray pencil. The photographic plate will then show, if it is limited to a strip a little wider than the length of the slit, a series of fine lines, like an optical spectrum, and each such set of lines is unique and belongs to one crystal only, or to an agglomerate of crystals.

The method of analysing a powdered material was devised and used by Debye and Scherrer, and also by Hull. The latter gives a description in the December (1917) number of the *Physical Review*.

The X-ray photographs of kaolinite and other crystals described in these notes were made by Mr. G. Shearer, whose account is attached.

THE ANALYSIS OF CERTAIN CLAYS, AND SILLIMANITE.

By G. SHEARER.

The following specimens were examined:—

(*a*) Two specimens of clay used in the porcelain industry.
(*b*) Four specimens of kaolinite.
(*c*) Two specimens of sillimanite.

Results. (*a*) Both these specimens show crystalline structure and give photographs with clearly defined lines. They appear to be different, although they have certain common features. It appears probable that they contain more than one crystalline substance, but one specimen is purer than the other. A comparison with the kaolinite photographs shows that there is a marked similarity between the photographs obtained from these substances and those from kaolinite. It appears, then, that kaolinite is certainly the leading constituent. The lines on the photograph are quite well defined, showing that the crystals are not excessively small.

(*b*) Four different specimens of kaolinite powder have been tested :

1. Dried at 100°.
2. ,, ,, 700°.
3. Calcined at 900°.
4. ,, ,, 1000°.

Nos. 1, 3, 4 show well marked crystalline structure, the fineness of the lines showing that the crystals are not exceedingly small (probably they are large enough to be seen with the microscope).

No. 2. Shows only mere traces of crystal structure ; instead of fine lines, only badly defined bands appear. This indicates that such crystals as are present are extremely minute (probably of the size of colloidal particles).

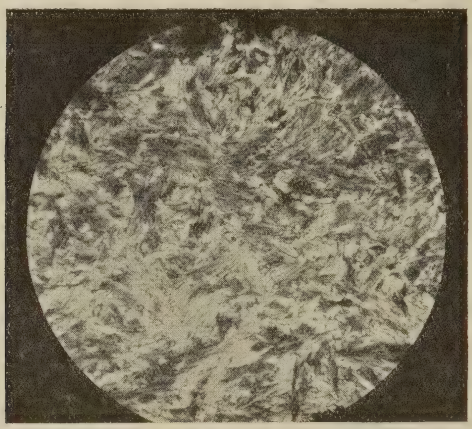
The X-ray "spectra" of Nos. 3 and 4 are the same but they are different from No. 1. All of them differ from that of sillimanite. The accompanying sketch of the positions of the principal lines shows the difference ; the thickness of the lines indicates roughly the intensity. The scales are approximately the same in all cases. In order to see whether any of the lines are the same in the different cases, more detailed experiments are necessary.

(*c*) The two specimens of sillimanite were :—

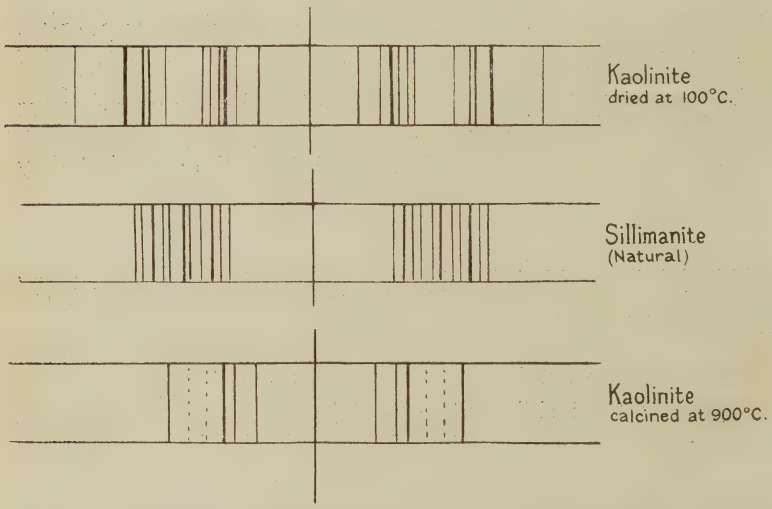
(I) Natural sillimanite (Fig. 2.)

(II) A piece of porcelain which contained a large percentage of sillimanite (Fig. 1).

Both give photographs showing marked crystalline structure and the lines occur in the same places in the two specimens. The nature of the lines is also the same, indicating that the crystals are not much smaller in the one case than in the other, but they are much more distinct on the photograph of the natural specimen. This is probably due to the presence in the second specimen of a large amount of practically amorphous matter. The radiation scattered from this, fogs the plate and masks, to a certain extent, the line spectra from the sillimanite.



Microphotograph of Sillimanite Rock. Practically the whole rock consists of fine-grained Sillimanite ($\times$ 60).



Diagramatic Representation of three of the Radiograms. (The thickness of the lines in the figures represents an approximate estimate of the relative intensity of the Spectral Lines).

Photographs of the kaolinite crystals, and chemical analyses were published in the TRANSACTIONS **11**, 169, 1912. Dr. A. Scott attempted to determine goniometrically the crystallographic contents, but found the crystals too small. We have to thank the Royal Worcester Porcelain Company for sending samples of sillimanitic porcelain.

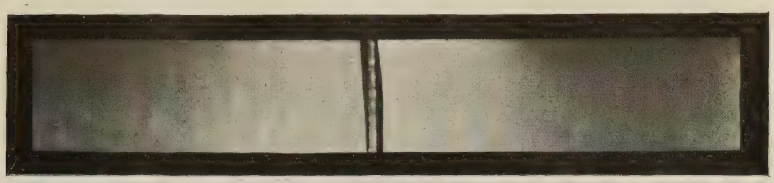


Fig. 1. Sillimanite Manufactured China, 3·5 cm.

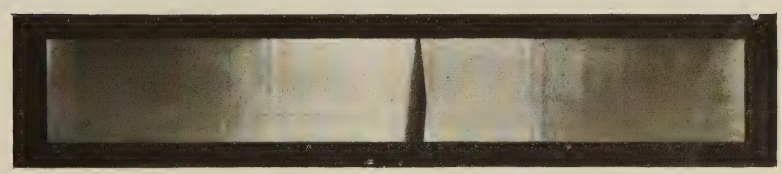


Fig. 2. Sillimanite Natural China, 3·5 cm.

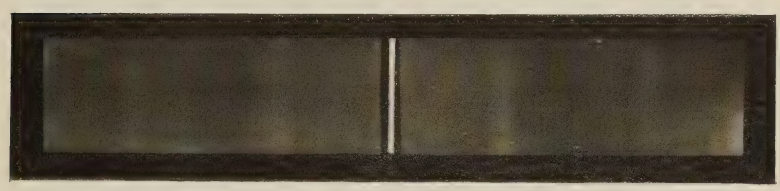


Fig. 3. Kaolinite 100°C, Nickel Filter 3·5 cm.

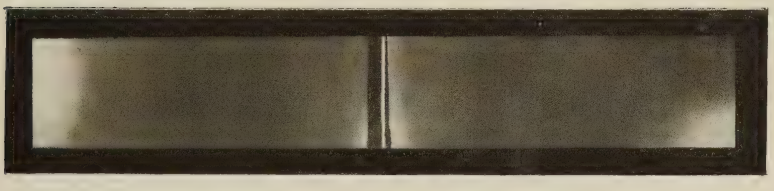


Fig. 4. Kaolinite.

Fig. 5. Kaolinite, 700°C, 3½ hrs.

Fig. 6. China Clay.

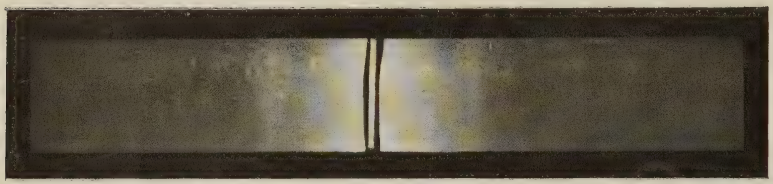


Fig. 7. China Clay.

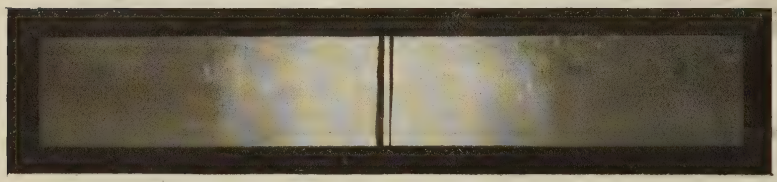


Fig. 8. China Clay.

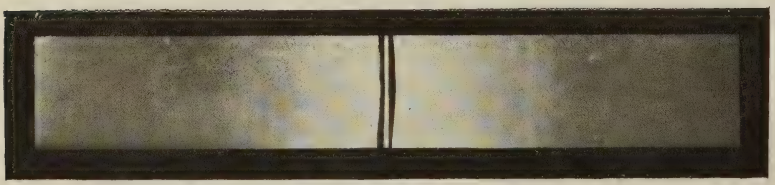


Fig. 9. China Clay.

X.—The Behaviour of Fireclays, Bauxites, etc., on Heating.

By H. S. Houldsworth, M.Sc., & J. W. Cobb, C.B.E., B.Sc., F.I.C.
(*Fuel Department, The University, Leeds.*)

THE changes which occur in clays and similar substances on heating are very difficult, and indeed impossible, to determine by purely chemical methods; we have followed others in attempting to derive as much information as possible by a study of physical changes with which chemical changes may be associated. The physical effects brought under observation are heat evolutions and absorptions, contractions and expansions, permanent and reversible, losses in weight and changes in specific gravity and porosity.

Part I.—The Change in Linear Dimensions.

Many workers have investigated the shrinkage or expansion of a clay on heating by firing a measured test piece to different temperatures and, after cooling, observing the change in length which had occurred. We have endeavoured to obtain a *continuous* record of the change in length of clay test pieces on burning. We used the apparatus devised for measuring the reversible thermal expansion of refractory materials*. Kaolin, a Dorset ball clay, Farnley fireclay, a Scottish fireclay, and Ayrshire bauxitic clay were examined, and their chemical analyses are given in Table 3.

The clay was first ground until it passed a 20-mesh standard (I.M.M.) sieve (maximum size of particle $\frac{1}{40}$"), and was then worked with water until it was plastic, and subsequently was moulded into test pieces 20cms. long. These were examined in the apparatus after air drying for several days. The furnace was heated very slowly as long as the clay expanded or showed no change in dimensions, but, whenever a shrinkage was observed the specimen was held at that temperature until no further decrease in length occurred. When the shrinkage had been completed the temperature was again slowly raised. The firing of the clays to 1,000°C. in this way took from two to three weeks, the temperature during the night being registered on a thread recorder. We will describe fully the course of an experiment for one of these substances. The others will be discussed more briefly.

Kaolin.

The specimen was heated at $1\frac{1}{2}$°C. per minute to 104°C. and expanded† but no further change in dimensions occurred to 130°C.

* Trans., **21**, 227, 1922.

† The expansions referred to in this paper were reversible thermal expansions and not permanent changes in dimensions.

The absence of expansion on heating from 104–130°C. was due presumably (see Part II.) to the expulsion of the hygroscopic moisture not removed on air drying. The rate of heating was then reduced to ½°C. per minute and the test piece expanded up to 280°C. The temperature in the night rose from 280°C. to 315°C. and the specimen had again expanded. It was then heated to 530°C. at ½°C. per minute and it continued to expand, but at this temperature a marked contraction started. The kaolin was maintained at 530°C. until it ceased to contract, about forty-eight hours being required. It was next heated to 610°C. at ½°C. per minute and was maintained overnight at this temperature without any further change in dimensions taking place. Next day, it was heated at about ½°C. per minute to 680°C. without any appreciable change in length taking place, but at this point a pronounced contraction started and took about forty hours for completion, the temperature being maintained at 680–710°C. No further change in dimensions was detected on heating at ½°C. per minute to 870°C., but here a rapid contraction took place, 25 hours being required to complete this shrinkage. The kaolin was then heated to 950°C. at ⅓°C. per minute without appreciable change in its dimensions, but a marked contraction was observed at this temperature, about 40 hours being required before the shrinkage ceased. The temperature was next slowly raised, without any further change in length occurring, to 1,080°C., where a further shrinkage took place. This was not followed out, owing to the danger of prolonged heating at so high a temperature to the nichrome winding of the furnace.

The results obtained were so surprising in their discontinuities, that it was felt necessary to repeat the experiment with a much longer time of heating, as it was thought these changes might then take place at lower temperatures, or that a progressive and gradual shrinkage might be observed instead of the shrinkage in stages. As we had found dehydration to be practically completed at 450°C. (see Part II), we considered it was necessary to determine with particular care whether the shrinkage observed at 530°C. in the previous experiment took place at a lower temperature on very slow heating. Ten days were taken to reach 530°C. in this second experiment (see Fig. 1.) temperatures being maintained overnight about 215°, 235°, 280°, 310°, 390°, 420°, 450°, and 475°C. without any shrinkage taking place, but a decrease in length again started about 530°C. When this contraction had been completed the temperature was raised very slowly, 22 days being taken to pass from 550–880°C., and a further 27 hours from 880–980°C. Small shrinkages were observed at 625°, 700°, and 780°C., and very pronounced contractions took place at 880°, 980°C. and 1,060°C. It would seem that, on more rapid heating, the small shrinkage at 625°C. was not detected until 680°–700°C. and so appeared to coincide with the contraction which took place at 700°C. The small decrease in length at 780°C. was not detected with the more

rapid heating. It is interesting to note that the clay expanded (thermal reversible expansion) from 530° to 625°C. and that in the temperature intervals between the other shrinkage points a very slight contraction took place with this extremely slow rate of heating (about 1–2°C. rise in temperature per hour). This experiment showed conclusively that the shrinkage of kaolin on heating to 1,100°C. took place in a number of stages, each shrinkage being completed at a definite temperature or in a temperature range of 10–20°C.

The experiment was also repeated with kaolin with a more rapid rate of heating, the temperature being raised at about 2°C. per minute except at the points where shrinkages took place. Very rapid shrinkages were observed at 550°, 680°, 700°, 880°, and 960°C. with slight thermal expansions taking place in the intermediate ranges.

The shrinkages were all irreversible changes, the test piece on cooling contracting steadily and having a coefficient of contraction approximately the same as a test piece fired in a works kiln to cone 06 (980°C.).

It appeared, therefore, that seven definite shrinkage points existed between 15–1,100°C. for kaolin, viz.: at 530°, 625°, 700°, 880°, 950°, and 1,060°C., the clay having a very small rate of contraction at intermediate temperatures when subjected to a prolonged heating, but expanding (reversible thermal expansion) when the heating was more rapid. The shrinkages at 625°C., 700°C., and 780°C. were considerably smaller than those taking place at 530°C., 880°C, 950°C., and 1,060°C.

Farnley Fireclay.

(See Fig. 1).

A slight shrinkage was observed about 100°C. due to the expulsion of hygroscopic moisture not removed on air drying and of water associated with any colloidal matter present in the clay. From 140°C. to 540°C. the specimen expanded steadily (reversible thermal expansion), no contraction being detected, although the rate of heating was very slow, five days being taken to reach 540°C., where a contraction of 0·15 per cent. took place. After the test piece had ceased to shrink at this temperature the heating was continued and the specimen expanded to 570°C. From this point to 600°C. the rate of expansion was considerably increased, due no doubt to the increase in volume caused by the inversion of the free α-quartz in the clay to β-quartz. Above 650°C. no further increase in length occurred. Five days were taken to pass from 650° to 880°C. and the shrinkage was steady and very slight. At 880°C. however, a rapid increase in the rate of shrinkage occurred. When all change in dimensions at 880°C. had ceased the temperature was slowly raised, but little change occurred in the dimensions of the test piece up to 950°C. where a marked contraction took

place. The length of the specimen did not change appreciably between 950° and 1,080°C., but at the latter temperature a rapid contraction started which was not followed out owing to the danger to the nichrome-wound furnace.

Summarising, definite and pronounced shrinkage points occurred at 540°, 880°, 950°, and 1,080°C. together with a slight shrinkage about 100°C. These changes were irreversible, as is seen from the cooling curve, which, however, shows the contraction on cooling between 600° and 550°C. due to the inversion of β to α-quartz.

Atlas (Scottish) Fireclay.

(See Fig. 1).

Atlas fireclay behaved very similarly to the Farnley fireclay, giving marked irreversible shrinkages at 100°–140°C., 540°, 880°, 980° and 1,050°C. with a rapid reversible expansion between 575° and 610°C. due to the inversion of the free α-quartz of the clay to β-quartz. The slow progressive shrinkage between 650° and 880°C. was greater than with the Farnley fireclay and was due, possibly, to the slower rate of heating in this range compared with that used for the Farnley clay, 11 days being taken instead of the 5 with the latter clay.

Ayrshire Bauxitic Clay.

(See Fig. 2.)

A highly aluminous clay (Ayrshire Bauxitic Clay) was studied next. It expanded steadily to 100°C. where a small contraction started. After this contraction ceased, very little expansion took place up to 250°C. Probably a very slight shrinkage annulled the thermal expansion. The specimen expanded steadily from this temperature to 530°C., 3½ days being taken to reach 530°C. At this point a large contraction began and took about 4½ days for completion. The test piece was next heated at about 10°C. per hour and a small thermal expansion occurred to 620°C. where a pronounced shrinkage took place which was completed after 4½ days heating at this temperature. The temperature was next raised at about 15°C. per hour and little change in dimensions could be detected until 700°C. was reached, when a contraction started, about 4½ days again being required to complete the shrinkage. The specimen expanded (reversible thermal expansion) on continuing the heating at about 15°C. per hour to 800°C., but a further pronounced decrease in length was observed at this point. The temperature was maintained approximately constant for 3½ days by which time the specimen had ceased to shrink. It was heated next to 880°C. at about 10°C. per hour and showed a slight thermal expansion, but a very rapid and large contraction started at this temperature and was completed after about 8½ days. The heating was continued at about 15°C. per hour to 950°C. without

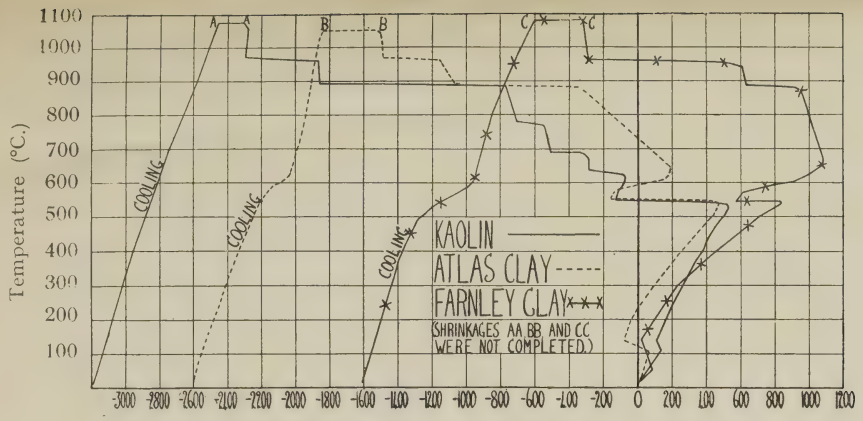


Fig. 1—Expansion per 20 cm. (100 divs.=0·1114 mm.)
% Shrinkage=No. of divs. ×·000557.

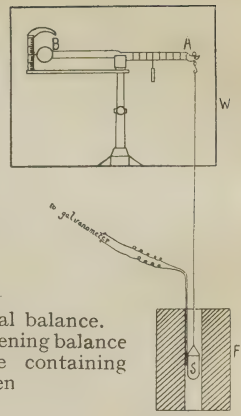


Fig. 3

A.B.—Westphal balance.
W.—Case, screening balance
S.—Silica tube containing specimen
F.—Furnace

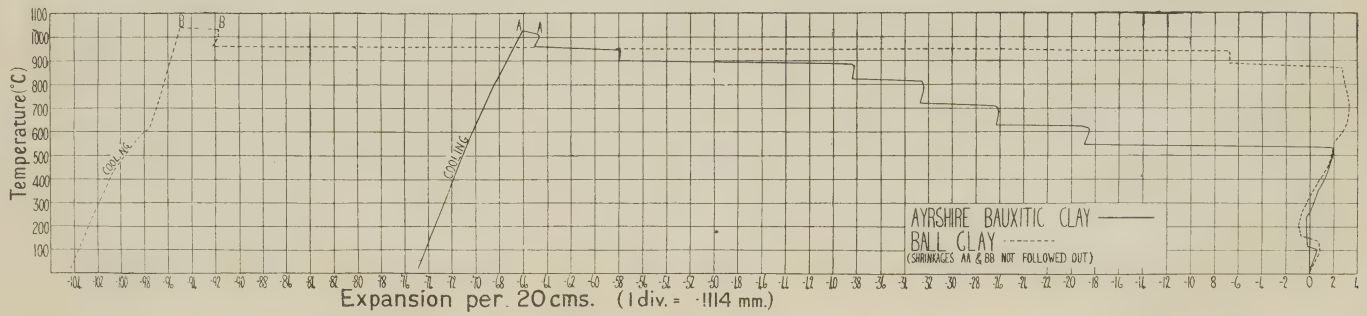


Fig. 2

any appreciable change in length occurring, but at this temperature a very pronounced and large contraction began. After 6 days this shrinkage was completed and the specimen was heated to 1015°C. at about 12°C. per hour. It expanded slightly (thermal expansion), but at this temperature a rapid shrinkage started. This was not completed owing to the danger to the furnace winding at this temperature. All the shrinkages observed were irreversible. It will be seen that this aluminous clay differed from the siliceous clays examined both in possessing a larger number of shrinkage points, viz. at 100°C., 530°C., 620°C., 700°C., 800°C., 880°C., 950°C., and 1,015°C., and also in the larger contractions which took place at these temperatures.

Ball Clay.

(See Figure 2.)

A Dorset ball clay expanded (thermally) to 100C°. and contracted slightly between 100 and 200°C. It showed marked irreversible contractions at 880°, 940°, and 1030°C. The contraction at 940–960°C. was very large, amounting to 4·75%, and required seventeen days for completion, while the contraction at 1030°C. was very rapid, but could not be completed owing to the danger to the furnace at this temperature.

The temperatures at which shrinkages were observed for the different clays examined are summarised in the following table :—

Table 1.

Kaolin	Farnley fireclay	Atlas (Scottish) fireclay	Ayrshire bauxitic clay	Ball clay
—	100–140°C. (slight)	100–140°C. (slight)	100°C. (slight)	100–200°C. (slight)
530°C.	540°C.	540°C.	530°C.	
625°C.	—	—	620°C.	—
700°C.	—	—	700°C.	—
780°C.	—	—	800°C.	—
880°C.	880°C.	880°C.	880°C.	880°C.
950°C.	950°C.	980°C.	950°C.	940°C.
1060°C.	1080°C.	1050C°	1015°C.	1030°C.

The close agreement in the temperatures at which shrinkages were observed with some clays, and the absence of some of these shrinkage points in other clays, are presumably bound up with differences in molecular or crystalline constitution and the changes induced in these by heat. Such changes may be expected to exhibit their effects in other directions, and in succeeding parts of this paper an attempt is made to determine how far the shrinkage effects can be correlated with others. It is quite plain, however, that the shrinkage of clays is not a continuous process but one which takes place in a number of stages (7 for kaolin), each stage being completed

at a definite temperature. The shrinkages of considerable magnitude are, generally speaking, found at almost the same temperatures in the different clays. Some points, such as the absence of the 530°C. shrinkage in Ball Clay, have no doubt a significance, but not one which we can explain at present.

Part II.—Loss in Weight.

Many experiments have been made previously to determine the loss in weight of clays after heating to known temperatures for varying times. As the result of the shrinkage work described in Part I., we decided that an experimental procedure was advisable which would indicate clearly losses of weight taking place sharply at defined temperatures, if such occurred. About 8 grms. of the material were placed in a silica tube closed at one end and suspended in an electrically heated furnace by means of a platinum wire attached to one arm (*A*) of a Westphal balance (See Fig. 3). Lead foil was wrapped round the end of the arm (*B*) of the balance until it compensated for the weight of the tube and contents. A loss of weight of ·005 grms. could be detected with the apparatus. The temperature of the furnace was taken with a thermocouple placed with its junction opposite the middle of the silica tube. The Westphal balance stood in a wooden case attached to the wall above the furnace, the platinum suspending wire passing through a small hole in the floor of the case. In this way the balance was screened effectively from convection currents and draughts.

The rate of heating was very slow when practically no loss of weight was taking place, and whenever an appreciable loss of weight occurred the temperature was maintained steady at that point until no further decrease in weight was detected after several hours heating. In this way the heating from 15–1,000°C. took from 2 to 3 weeks.

The accuracy of the method was first tested by examining finely ground quartzite, of which the loss of ignition determined in the ordinary way was 0·26 per cent. Practically no loss in weight could be detected at any point and the loss on heating to 1,000°C. was 0·25 per cent. This experiment showed conclusively that convection currents in the furnace did not interfere in any way with the readings of the balance.

(*a*) *Kaolin*—See Fig. 4.

A loss in weight of 0·8 per cent. occurred on heating air-dried kaolin slowly to 130°C., but little loss could then be detected until 425°C. was reached. The temperature was maintained at 425° 450°C. for ten days until the rate of decrease in weight was apparently negligible, the total loss in weight being then 11 per cent. The rate of decrease in weight was then slow and progressive up to 850°C. which was attained after eight days further heating, and no further change in weight occurred up to 1,000°C., the loss in weight then amounting to 13·2 per cent. compared with the value of 12·9

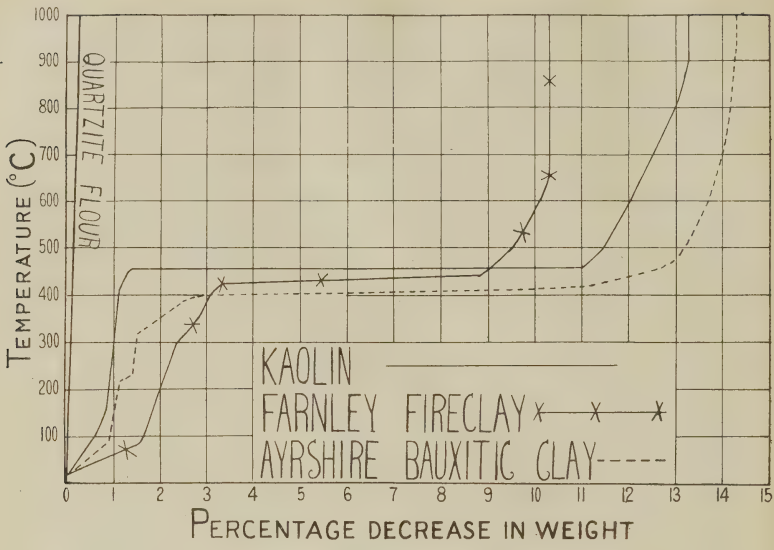


Fig. 4

per cent. obtained for the loss on ignition determined in the usual way (by igniting in a platinum crucible in a muffle at 1,000°C.)

It seems, therefore, that the dehydration of the clay material does not take place in stages but is effected between about 420–450°C. on prolonged heating. It is possible that the loss in weight from 450–1,000°C. might have been brought about by continuing the heating at 450°C., but that an extremely lengthy period of time (running into months) would have been necessary for the purpose.

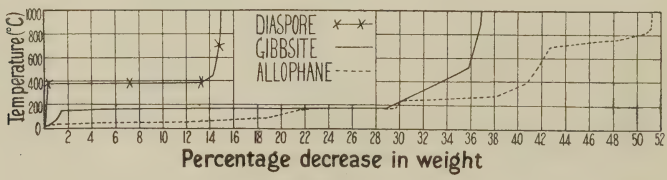


Fig. 5.

(*b*) *Hydrated Alumina.*

Diaspore ($Al_2O_3 \cdot H_2O$) (From Kossoibrod, Ekaterinburg, Ural) See Fig. 5. No appreciable loss in weight was detected on slowly heating diaspore to 370°C., but from 370–400°C. a large decrease in weight (13%) occurred, 8 days heating in this temperature range being required before the loss in weight ceased. A further loss in weight of 1% took place from 420–450°C., due possibly to some clay being admixed with the diaspore, but little further loss took place up to 1000°C.

Gibbsite ($Al_2O_3.3H_2O$). (From Fort Henry, New York). See Fig. 5. A decrease in weight of about 1·25% was observed up to 100°C. but from 160–190°C. a very pronounced and large loss in weight, amounting to about 29%, took place, the temperature being maintained in this range for ten days. From 200–500°C. the loss of weight took place more slowly, amounting to about 5% in twelve days, while from 500–1000°C. very little change in weight was noted.

(*c*) *Bauxites*—See Fig. 6.

Red Bauxites.—The red bauxite lost about 2·7 per cent. of its weight on slowly heating to 50°C. It then showed only a small change in weight up to 350°C., which was reached after 5 day's heating. After 5½ days at 350°-410°C. the rate of loss in weight became very small and little further loss occurred up to 1,000°C., which was reached in a further 3½ days. It would seem that the hydrated alumina present in this bauxite consisted of one form only, dehydrating at one

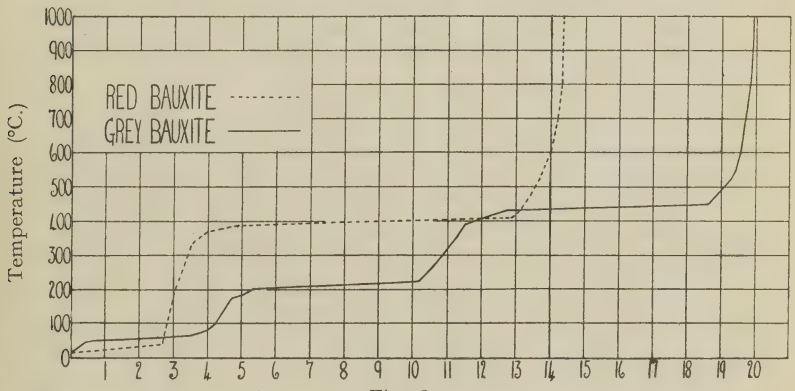


Fig. 6
Percentage decrease in weight.

temperature. These results, supported by those obtained by the method of investigation recorded in Part III., would indicate that in this bauxite the alumina occurred as diaspore ($Al_2O_3 \cdot H_2O$).

Grey Bauxite.

The grey bauxite showed rapid losses in weight at 15°–100°C., 200°–230°C., and 400°–450°C. The first was due to the loss of hygrosopic moisture and the water associated with the colloidal matter present. The second, no doubt, resulted from the dehydration of some of the free alumina present, while the third would be caused by the dehydration of the clay material present together with that of any alumina present in the form occurring in the red bauxite. It would seem that much of the free alumina was present as gibbsite ($Al_2O_3.3H_2O$).

The results obtained with the bauxite agreed with those described by Bigot (see Part III.) except that they were brought

about at rather lower temperatures, on the prolonged heating given in our experiments, than those at which he detected the changes by simply weighing after 1 hour's heating at various temperatures. The thermal phenomena associated with these changes occur on more rapid heating at higher temperatures (see Part III.) and at temperatures more in harmony with Bigot's results, which were also got under conditions of more rapid firing. The thermal phenomena observed on heating diaspore ($Al_2O_3 \cdot H_2O$) and gibbsite ($Al_2O_3 \cdot 3H_2O$) showed that the former had an absorption of heat at 470°C. and the latter at 240°C.

Reviewing all these results it would seem, then, that the grey bauxite contained gibbsite, clay, and possibly a little diaspore, while the red bauxite lost weight in a similar manner to diaspore on heating, but exhibited a heat evolution at 1,000° which was not detected with diaspore.

Farnley Fireclay—See Fig. 4.

The behaviour of the Farnley fireclay is similar to that of kaolin, the actual loss in weight, however, being smaller.

Ayrshire Bauxitic Clay—See Fig. 4.

This clay decreased in weight by about 1 per cent. on heating to 100°C., and afterwards showed no further loss in weight to 320°C., except a slight loss at 220°C. From 320–400°C. (five days being taken to pass through this range), the weight decreased slowly, but a rapid loss in weight started at 400°C. and was completed about 450°C. after twenty days' heating, the weight having then decreased by 13 per cent. The clay now lost weight slowly to 1,000°C., eleven days being taken to reach this temperature. The total loss was 14·3 per cent. It is suggested that the small decreases in weight at 220°C. and 320°–400°C. are due to the dehydration of the hydrated alumina (which can occur as $Al_2O_3 \cdot H_2O$ and $Al_2O_3 \cdot 3H_2O$) present in the clay. The large loss in weight at 400°–460°C. resulted from the decomposition of the clay material proper, as well as from any remaining hydrated alumina present as diaspore.

Allophane ($Al_2O_3 \cdot SiO_2 \cdot 5H_2O$)—See Fig. 6.

Allophane showed a large loss of weight between 15°C. and 90°C. and this was followed by a further large decrease in weight between 120°C. and 180°C., the two changes being associated with the absorption of heat starting at about 50°C. and completed at 140°C. (see Part III.) From 180°–240°C. very little change in weight occurred, but from 240°–280°C. the weight decreased by 7 p. ct. This decrease in weight would correspond with the endothermic reaction observed at 270°C. (see Part III.), the small difference in temperature being due to the large differences in the times of heating in the two experiments. The rate of loss in weight then decreased considerably and from 400°–670°C. was very small, but was considerably increased from 670°–820°C. Above this temperature there was no further change in weight to 1,000°C. This

loss in weight would correspond with the heat absorption detected at 860°C. on rapid heating. It would thus appear that allophane dehydrates in four stages.

The results obtained in this part of the work are summarised in Table 2. The general discussion of their relation to the shrinkage results is postponed.

TABLE 2.

TEMPERATURES AT WHICH DECREASES IN WEIGHT OCCURRED.

Kaolin	Farnley Fireclay	Ayrshire Bauxitic Clay	Diasporc ($Al_2O_3.H_2O$)
15–100°C.	15–90°C.	15–90°C.	
		220°C. (slight)	
		320–390°C. (slight)	370–400°C.
420–450°C.	425–450°C.	400–470°C.	

TABLE 2—*Continued.*

Gibbsite ($Al_2O_3.3H_2O$)	Red Bauxite	Grey Bauxite	Allophane ($Al_2O_3.SiO_2$ $5H_2O$)
15–90°C.	20–50°C.	50–80°C.	15–90°C.
			120–180°C.
		200–220°C.	230–280°C.
160–190°C.	350–410°C.		
		390–450°C.	
			670–820°C.

Part III.—Thermal Phenomena.

This part of our work deals with the study of heat evolutions and absorptions and the method followed has already been applied for a similar purpose by one of us in a study of similar thermal phenomena observable in the carbonisation of coal (Hollings and Cobb, *Trans. Chem. Soc.*, **107**, 1106, 1915.)

The thermal phenomena occurring in clays on heating were first examined by H. le Chatelier in 1887 (Le Châtelier, *Bull. Soc. Min.*, 1887, **10**, 207), and his preliminary survey has since been extended by many investigators.*

*Mellor & Holdcroft, TRANS., **9**, 94, 1910.
,, **10**, 161, 1912.
,, **13**, 83, 1914.
Ashley .. *J. Ind. Eng. Chem.*, **3**, 91, 1911.
Rieke .. *Sprech.*, **44**, 637, 653, 1911.
Sokolov .. *Ker. Rundschau*, **20**, 365, 1912.
Tonind. Ztg., **36**, 1107, 1912.
Wöhlin .. *Silikat-Zeitschrift*, **1**, 225, 1913.
Samoilov .. *Bull. Acad. Imp. Sci.*, **11**, 779. 1914

The methods adopted have consisted essentially in taking the time-temperature curve of a thermocouple embedded in the specimen and comparing it with the curve given by a second couple placed in some standard reference substance heated alongside it. If at some temperature the former heating curve lags behind the latter, a change involving an absorption of heat is taking place in the specimen, but if at some point the rate of heating of the specimen is greater than that of the standard substance an exothermic reaction is occurring in the test-piece. As a result of the critical points he observed, Le Châtelier divided clays and certain hydrous aluminium silicates into five groups, which he subsequently reduced to three. Ashley found two distinct lags with fireclay, one occurring between 200–300°C. and the other starting a little above 500°C. and being completed between 570°C. and 620°C. He attributed the first lag to the expulsion of mechanically held water and the second to the decomposition of the kaolinite molecule. At about 925°C. an acceleration took place in the heating curve indicating that an exothermic reaction was occurring. Mellor and Holdcroft obtained similar results for fireclays, but found the first lag absent with kaolin. They also examined the behaviour of alumina, silicic acid, and various hydrated compounds of alumina and silica. Similar results were obtained by Rieke, Sokolov, etc. Various theories have been advanced as to the mode of decomposition of the kaolinite molecule at 500°C. Knote (*Trans. Amer. Ceram. Soc.*, **12**, 226, 1910) suggested that two molecules decomposed to form one molecule of $Al_2O_3 \cdot SiO_2$ + one molecule of $Al_2O_3 \cdot 3SiO_2$. Mellor deduced that the clay decomposed into free silica, free alumina, and water, while Samoilov concluded that a special form of allophane ($Al_2O_3 \cdot SiO_2$) and silica were formed. Similarly the acceleration in the heating curve observed about 925°C. has been ascribed by Knote to a recombination of the silicates formed at 500°C. resulting in the production of $Al_2O_3 \cdot 2SiO_2$, by Ashley to the possible formation of sillimanite ($Al_2O_3 \cdot SiO_2$) and by Mellor to the polymerisation of the alumina set free at about 500°C. The method used so frequently was not a very delicate one, although in the hands of skilled experimenters it has yielded excellent results. The exact location of the critical points was not possible as they varied with the rate of heating, while Mellor (TRANS., **16**, p. 77, 1916), stated: "It might be added that there are signs of other critical points in the different spacing of the half-minute dots of the recorder, but the method is not sensitive enough to enable definite statements to be made." We, too, felt that molecular changes involving only small thermal effects might have been overlooked, and with the object of testing this, and in the hope of obtaining data which would aid in the interpretation of some of the results obtained in our experiments on the shrinkage of clays, a different method was adopted. The method selected was devised and used by Roberts-Austen in his classical researches

on the transition points of alloys and has since been used with great success in metallurgical investigations, as well as by Fenner in his study of the reversible changes occurring in silica. The specimen (X) (see fig. 7.) and a standard reference piece (S), which does not

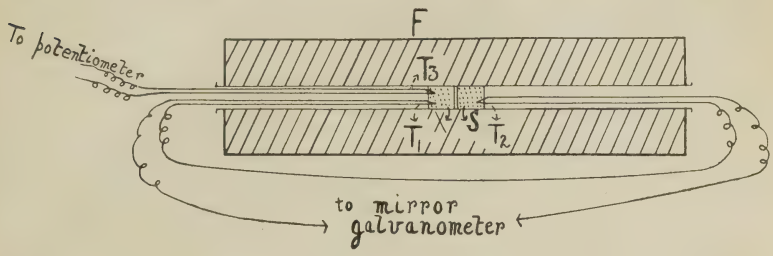


FIG 7.

F—electrical furnace; X—test piece;
S—standard reference material; $T_1T_2T_3$ thermo-couples.

exhibit thermal discontinuities on heating, were placed very near each other, but not quite touching, in an electrically heated furnace. One thermocouple (T_1) was embedded in the test-piece, and another (T_2) in the standard material and the two couples were connected in opposition through a sensitive galvanometer (G_1). If the portion of the furnace occupied by the specimen and standard were uniformly heated, and if the thermal capacities of the two were the same, no current would flow through the galvanometer G_1, except when some reaction involving heat absorption or emission was taking place in the specimen. The direction of the deflection will depend upon the character of the thermal change involved. If the portion of the furnace occupied by the specimen and test piece were not all at the same temperature, or if the thermal capacities of the two differed, the galvanometer would show a deflection, but any thermal changes occurring in the specimen would cause sudden changes in the deflection of the galvanometer. The temperatures at which the transformations took place were determined by a third couple embedded in the test-piece, its electromotive-force being balanced against that along a portion of a Carpenter-Stansfield potentiometer. The couple was calibrated by determining the points of balance when it was placed in steam, and in lead, aluminium, salt and copper at their melting points. The furnace was heated at about 8°C. per minute and the readings of G_1 and G_2 were taken every minute. The deflection of the galvanometer in the differential circuit was plotted against the actual temperature of the test piece, negative deflections indicating endothermic and positive exothermic reactions. The furnace was well lagged and so the rate of cooling was too small to allow good cooling curves to be taken. Instead of making such measurements the furnace was reheated the next day without displacing

or altering the test pieces in any way. It was thus possible to determine whether the thermal changes noted on the first heating of the raw clay, etc., were associated with permanent or with reversible changes in the material. The interpretation of the curves is for various reasons difficult to effect with certainty, but is facilitated by a careful comparison in each case of the curve obtained on a first heating with that resulting from a second heating, made, that is, after the disturbances of the irreversible thermal effects have been eliminated.

Satoh (*J. Amer. Ceram. Soc.*, **4**, 182, 1921) examined Japanese kaolinite by a similar method, but, unfortunately, he took quartz sand as his reference substance, a most unsuitable material for a standard owing to the transformations it undergoes on heating. In addition to the known reactions at about 500°C. and 950°C. he found a further exothermic change between 1,200°C. and 1,300°C. which he ascribed to the formation of amorphous sillimanite.

In our earlier experiments we used a small cylinder of platinum as our standard reference substance. We found, however, that kaolin after heating to 1,200°C. showed no transformations involving heat changes and in our later experiments we used this burned kaolin as a reference substance, as its thermal capacity was more nearly equal to that of the specimens examined than was that of the platinum cylinder.

The results of the chemical analyses of the materials used are given in Table **3**.

Results obtained from various materials under test as described above.

Silica.

(*a*) Powdered silica glass (vitreosil) showed no thermal effects.

(*b*) Air-dried amorphous silica prepared from water glass by precipitation with hydrochloric acid showed an absorption of heat starting at 80°C. and completed about 130°C. This thermal effect was probably due to the expulsion of water from the colloidal material. An exothermic reaction was observed at 330°C. and was completed at 355°C. A reheating of the specimen showed that both these changes were irreversible.

(*c*) Pure amorphous silica prepared from silicon fluoride had an irreversible exothermic reaction starting at 365°C., and completed at 405°C.

Alumina (see Fig. 8).

(*a*) Alumina was obtained by calcining aluminium nitrate at 700°C. An irreversible molecular change involving the

liberation of heat was observed at 1,060°C. and was completed at 1,130°C. This effect may be associated with the polymerisation of alumina as Mellor has suggested. It occurred at a considerably higher temperature than he

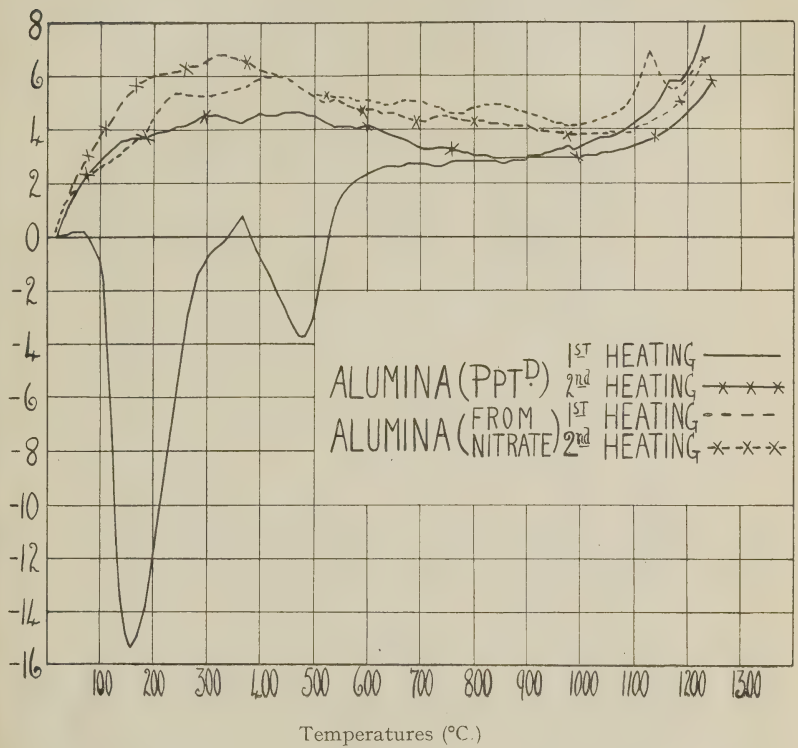


FIG. 8

found in his experiments, but our observation agreed with that of Wöhlin, who gave 1,060°C. for this change.

(*b*) Alumina was precipitated from a hot solution of aluminium nitrate with ammonia. The precipitate was filtered, washed, redissolved in hydrochloric acid, re-precipitated with ammonia and finally washed until free from chlorides. After air-drying for some weeks, it was examined and showed two endothermic reactions, one starting at 70°C. and completed at 155°C., and the second beginning at 365°C. and completed at 480°C. No thermal effect was detected at 1,060°C. Both the changes observed were irreversible, and were possibly due to the expulsion of

TABLE 3.

ANALYSIS OF THE CLAYS AND BAUXITES EXAMINED.

	Kaolin	Ball clay	Farnley Fireclay	Atlas (Scottish) Fireclay	Ayrshire Bauxite	Aluminous Shale	Grey Bauxite	Red Bauxite
Hygroscopic moisture	0·14	1·24	—	0·12	0·75	—	23·16	12·16
Loss on ignition	12·78	11·36	9·36	12·78	13·96	12·28		
Silica (SiO_2)	46·20	51·62	63·48	51·14	36·65	45·54	29·82	0·75
Alumina (Al_2O_3)	38·49	32·09	22·39	31·89	43·83	36·17	46·52	87·15
Titanium dioxide (TiO_2) ..	—	—	1·10	0·87	3·20	1·25		
Ferric oxide (Fe_2O_3)	0·58	1·23	1·33	2·46	0·67	2·25		
Lime (CaO)	0·30	0·75	0·70	0·40	0·49	Nil	0·53	0·25
Magnesia (MgO)	0·19	0·69	0·52	0·33	—	0·26	—	—
Soda (Na_2O)	0·81	1·55	0·88	0·22	0·57	0·76		
Potash (K_2O)	0·65	0·59	0·47			1·66		

water taking place in two stages, a question, however, which is receiving further study.

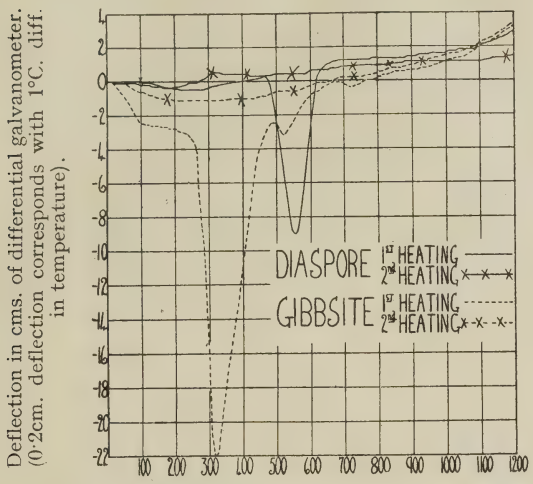

Deflection in cms. of differential galvanometer. (0·2cm. deflection corresponds with 1°C. diff. in temperature).
DIASPORE 1st HEATING
2nd HEATING
GIBBSITE 1st HEATING
2nd HEATING
Temperature (°C.)

FIG. 9.

(*c*) Diaspore ($Al_2O_3 \cdot H_2O$) (see Fig. 9). Diaspore showed only one thermal effect, viz. : an absorption of heat starting at 470°C. (completed at 555°C.) The change was irreversible, and was probably due to dehydration.

Gibbsite ($Al_2O_3.3H_2O$) (see Fig. 9). Gibbsite (from Fort Henry, New York) exhibited a large absorption of heat, beginning at 240°C completed at 320°C.) This change was irreversible, and was due to dehydration. A small endothermic reaction was observed at 500°C., probably due to the presence of a small amount of clayey material in the gibbsite.

Bauxites (see Fig. 10). Two bauxites, an Irish grey bauxite and a red bauxite, were examined. Their analyses are shown in Table 3. Interesting differences were found in their behaviour. The red bauxite had an endothermic reaction starting at 490°C. (completed at 565°C.) which was probably due to dehydration. An exothermic reaction started at 1,000°C. (completed at 1,070°C.) and may be due to the polymerisation of alumina. Both the changes were irreversible.

The grey bauxite showed a heat absorption up to about 180°C. due to the expulsion of water from the colloidal matter present. A second endothermic reaction started at 300°C. (completed at 365°C.) and this was followed by another change involving an absorption of heat at 510°C. (completed at 620°C.). The two latter

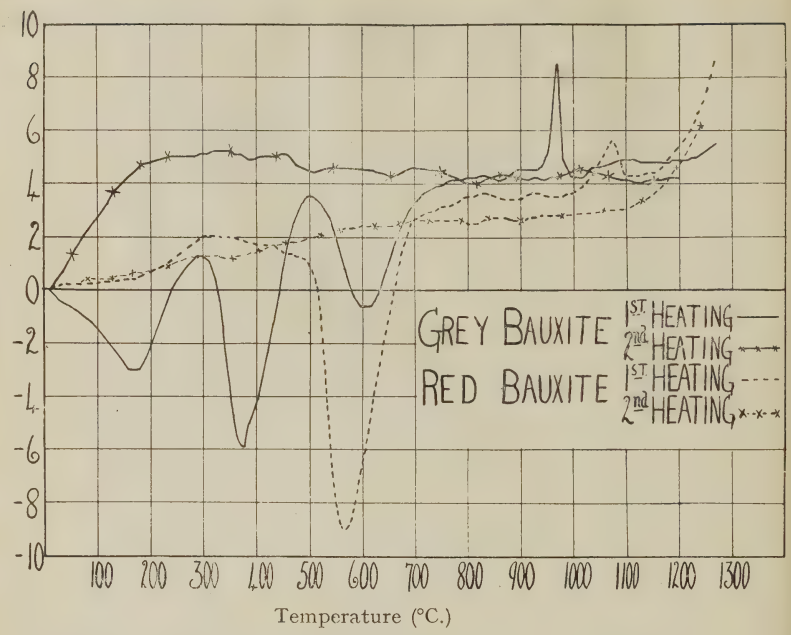


FIG. 10

changes were caused by the expulsion of the water from the bauxite in two stages. It will be seen from Table 1 that the loss on ignition of the grey bauxite was 23·16%, while that of the red bauxite was only 12·16%. Bigot (*Comptes rend.*, **174**, 1232-1235, 1922) showed that bauxites could be divided into two classes, one containing less than, and the other more than, 14% of water. He found that the latter lost their water in two stages, viz.: at 300°C. and 500°C., while the former had no appreciable loss in weight below 500°C. Bigot's results are thus in accordance with the observations we have made, and with our investigations of the loss in weight of bauxites on heating (see Part II). The heat absorbed at 510°C. was largely used in the decomposition of the clay admixed with the bauxite. A sharp exothermic reaction started at 940°C. (completed at 965°C.), and may be due to the polymerisation of alumina which thus took place at a lower temperature than with the red bauxite. Possibly this may be due to the transformation point being lowered by the presence of clay in the grey bauxite in a manner analogous to the lowering of the transformation points of alloys by the presence of small amounts of other substances. It may, however, be due merely to the clay admixed with the bauxite. A reheating of the grey bauxite showed that all the changes noted were irreversible.

Hydrated Compounds of Alumina and Silica.

(*a*) *Kaolin*, (Fig. 11) showed two changes. An endothermic reaction began at 500°C. (completed at 570°C.), and a large and sharply defined exothermic change started at 950°C. and was completed at 980°C. The theories advanced for these changes by Ashley, Mellor and Holdcroft, Knote, Samoilov, etc., have been mentioned previously. The reheating curve was interesting as it represented the

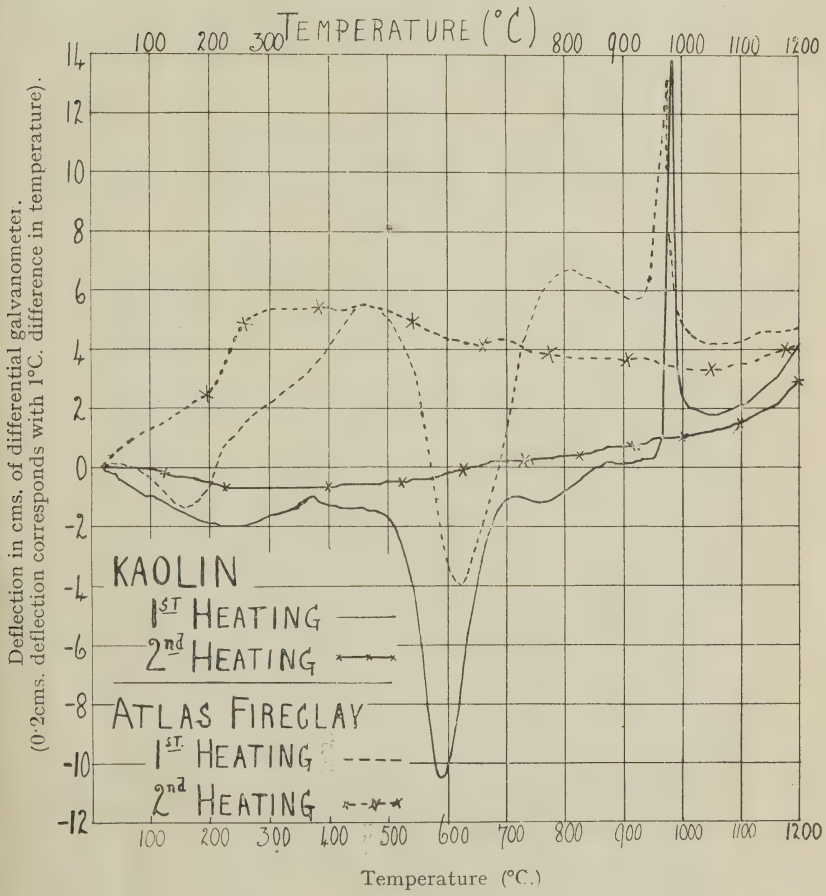

TEMPERATURE (°C)
100 200 300 800 900 1000 1100 1200
14 12 10 8 6 4 2 0 -2 -4 -6 -8 -10 -12
Deflection in cms. of differential galvanometer.
(0·2cms. deflection corresponds with 1°C. difference in temperature).
KAOLIN
1ST HEATING
2nd HEATING
ATLAS FIRECLAY
1ST HEATING
2nd HEATING
100 200 300 400 500 600 700 800 900 1000 1100 1200
Temperature (°C.)

FIG. 11

"blank" curve of the apparatus, being obtained for burned kaolin against a burned kaolin standard.

(*b*) *Fireclays* (Fig. 11). The curve shown for Atlas (Scottish) fireclay was taken against the platinum standard and the effect of the difference in the thermal capacity of the platinum and the clay in displacing the deflections from zero was shown on comparing with the curve obtained for kaolin. In addition to changes similar to those observed with kaolin, an endothermic reaction took place at 80°C. (completed at 160°C.) and was probably associated with the expulsion of water from the colloidal matter present in the clay. The results obtained for the various clays examined are collected in Table 4. It will be seen that the exothermic change observed at 950°C. in kaolin occurred at a slightly lower temperature in all the clays examined, except that of the highly aluminous Ayrshire clay.

TABLE 4.

	Endothermic.	Endothermic.	Exothermic.
Kaolin	—	500°C.	950°C.
Ayrshire Bauxitic clay ..	—	530°C.	950°C.
Dorset Ball clay	110°C.	500°C.	920°C.
Farnley fireclay (Yorkshire)	90°C.	510°C.	910°C.
Atlas ,, (Scottish)	80°C.	490°C.	930°C.
Aluminous shale (Kilwinning)	90°C.	510°C.	920°C.
Halifax clay after experimental electro-osmosis	90°C.	520°C.	915°C.

(*c*) *Pyrophyllite* ($Al_2O_3 \cdot 4SiO_2 \cdot H_2O$) (Fig. 12). Pyrophyllite from Brewer's Mine, Chesterfield, S. Carolina, showed a slight heat-absorption at 480°C. which may be due to the presence of clay as an impurity. It showed a change quite distinct from those associated with clays at 720°C. where an absorption of heat started which was completed at 830°C. This change was irreversible.

(*d*) *Allophane* ($Al_2O_3 \cdot SiO_2 \cdot 5H_2O$) (Fig. 12). Allophane (from Woolwich) gave a very interesting curve. An endothermic reaction started at about 50°C., was completed at 140°C., and was followed by a similar reaction starting at 270°C. (completed at 350°C.). No change was observed at 500°C., but a third endothermic reaction was observed at 860°C. (completed at 905°C.) and this was followed at 950°C. (completed at 970°C.) by a slight exothermic change. All the changes were irreversible. The curve obtained for allophane did not give any support to Samoilov's theory

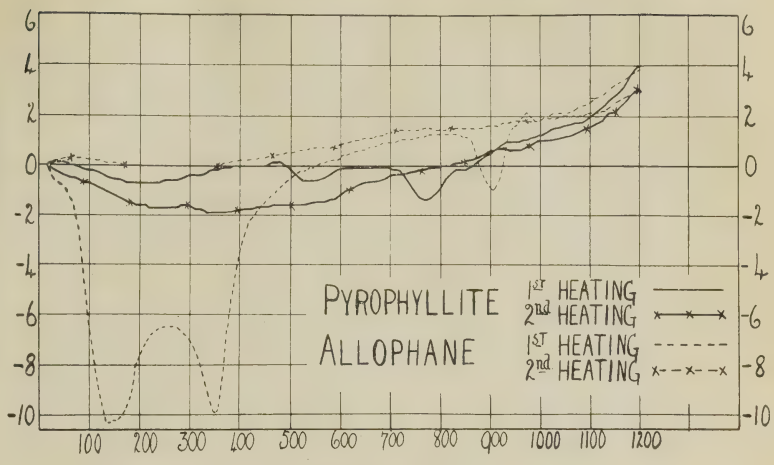


FIG. 12.

that fireclays break down at 500°C. into a mixture of allophane and silica. The various endothermic reactions are probably due to the expulsion of water in stages (see Part 2)..

(*e*) *Halloysite* (?) ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O \cdot Aq$) (from Loschaitzen-Tal, Bohemia). This showed three thermal effects, viz.: an absorption of heat at 50°C. (completed at 130°C.) and at 490°C. (completed at 560°C.) and a heat evolution at 880°C. (completed at 930°C.). Its behaviour was therefore similar to that of fireclay, except that the exothermic reaction took place at about 40°C. lower than for the fireclays.

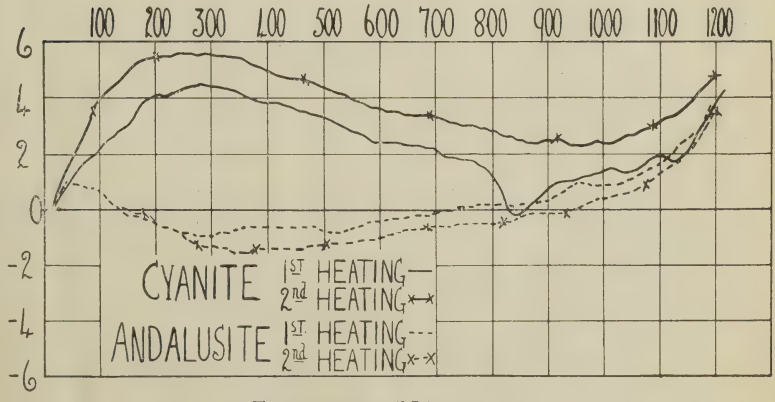


FIG. 13.

Unhydrated Compounds of Alumina and Silica.

(*a*) *Cyanite* ($Al_2O_3 \cdot SiO_2$). Fig **13**. Cyanite behaved differently from the substances previously examined. It showed only one thermal change, viz. : an irreversible endothermic reaction at 775°C. (completed at 850°C.).

(*b*) *Andalusite* ($Al_2O_3 \cdot SiO_2$) (from India). Fig. **13**. No change involving a definite thermal effect was noted with andalusite, although the curve suggested the possibility of a slight exothermic reaction at 940°C.

(*c*) *Sillimanite* ($Al_2O_3 \cdot SiO_2$). Fig. **14**. Two samples of sillimanite were examined. Sillimanite from Pennsylvania (U.S.A.) gave no evidence of thermal changes. Sillimanite from India showed a small endothermic reaction at 480°C. and an exothermic reaction at 950°C., but these are possibly caused by a small amount of clay material present in the specimen.

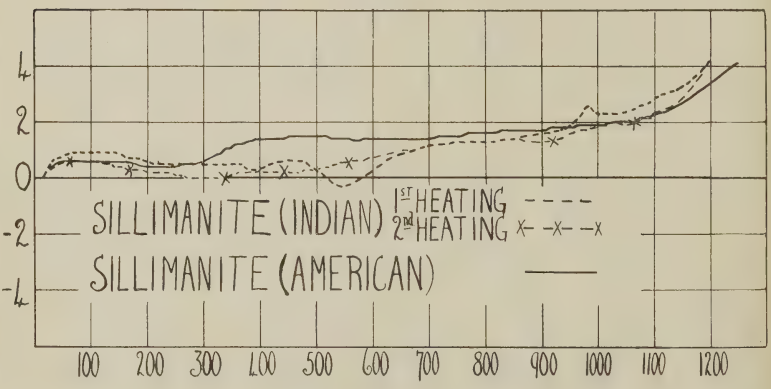


FIG. 14.

The results obtained for compounds of the form $Al_2O_3 \cdot SiO_2$ therefore gave no support to the theory that a clay breaks down into $Al_2O_3 \cdot SiO_2$ and SiO_2 at 500°C.

The results of our experiments are summarised in Table **5**.

In considering the results obtained by this method of examination the following points emerge:

(*a*) Kaolin and all the clays and shales examined show distinct heat absorption at a temperature of 500–530°C. and heat evolution at a higher temperature.

(*b*) This heat evolution occurs at a temperature of 1060–1130°C. with pure alumina made by calcining aluminium nitrate at 700°C., but at a temperature lower to an extent of about 100°C. with the bauxites and clays, possibly on

TABLE 5.

Substance.	Formula.	Temperature of previous heating.	Thermal changes observed.	
			(*a*) Heat absorption.	(*b*) Heat evolution.
Silica (vitreous)	SiO_2	1700°C.	None	None
Silica (precipitated, containing soda) ..	$SiO_2 \cdot xH_2O$ + soda		80°C. (completed 130°C.)	330°C. (completed 335°C.)
Silica (from silicon fluoride)	$SiO_2 \cdot 2H_2O$			365°C.
Alumina (by calcination from nitrate)	Al_2O_3	700°C.	None	1060°C. (,, 1130°C.)
Alumina (precipitated) ..	$Al_2O_3 xH_2O$		70°C. (completed 153°C.) 365°C. (,, 480°C.)	None
Diaspore	$Al_2O_3 \cdot H_2O$		470°C. (,, 535°C.)	None
Gibbsite	$Al_2O_3 \cdot 3H_2O$		240°C. (,, 320°C.) 500°C. (slight)	None
Bauxite red			490°C. (completed 565°C.)	1000°C. (completed 1070°C.)
Bauxite grey			up to 180° 300°C. (completed 365°C.) 510°C. (,, 620°C.)	940°C. (,, 965°C.)
Kaolin	$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$		500°C. (,, 570°C.)	950°C. (,, 980°C.)
Fireclays			80°C. (,, 160°C.) 490–530°C.	910–950°C.

TABLE 5—continued.

Substance.	Formula.	Temperature of previous heating.	Thermal changes observed.	
			(*a*) Heat absorption.	(*b*) Heat evolution.
Pyrophylite	$Al_2O_3 \cdot 4SiO_2 \cdot H_2O$		480°C. (completed 590°C.) 720°C. (,, 830°C.)	None
Allophane	$Al_2O_3 \cdot SiO_2 \cdot 5H_2O$		50°C. (,, 140°C.) 270°C. (,, 350°C.) 860°C. (,, 905°C.)	950°C. (completed 970°C.)*
Halloysite (?)	$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ Aq.		50°C. (,, 130°C.) 490°C. (,, 560°C.)	880°C. (,, 930°C.)
Cyanite	$Al_2O_3 \cdot SiO_2$		775°C. (,, 850°C.)	None
Andalusite	$Al_2O_3 \cdot SiO_2$		None	None†
Sillimanite American ..	$Al_2O_3 \cdot SiO_2$		None	None
Sillimanite India	$Al_2O_3 \cdot SiO_2$		480°C.‡	950°C.‡

*The heat evolution was slight.
†Possibly a very slight heat evolution at 940·C.
‡The changes were slight and possibly due to small amounts of clay material present.

TABLE 6.

	100°C	120-180°C.	220°C.	240°C.	270°C.	300°C.	330°C.	350-400°C.	365°C.	400-450°C.	480-520°C.
Silica.											
Vitreous (SiO_2)											
Ppted from water glass	Ha.						He.				
Ppted pure ($SiO_2 \cdot 2H_2O$)									He.		
Alumina.											
By calcining nitrate (Al_2O_3)											
Ppted. ($Al_2O_3 \cdot x\ H_2O$)	Ha.								Ha		
Diaspore ($Al_2O_3 \cdot H_2O$)								L.			Ha.
Gibbsite ($Al_2O_3 \cdot 3H_2O$)	L.	L.		Ha.							Ha slight
Bauxites.											
Red	L.							L.			Ha.
Grey	L.		L.			Ha.				L.	Ha.
Clays.											
Kaolin ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$)	L.									L.	Ha.
Farnley (Yorkshire)	S.Ha.L.									L.	Ha.
Atlas (Scottish)	S. Ha.										Ha.
Ayrshire	S. L.		L. slight							L.	Ha.
Ball Clay	S. Ha.										Ha.
Other Hydrated Cpds. of Al_2O_3 & SiO_2											
Pyrophyllite ($Al_2O_3 \cdot 4SiO_2 \cdot H_2O$) ..											Ha.
Allophane ($Al_2O_3 \cdot SiO_2 \cdot 5H_2O$) ..	Ha. L.	L.	L.		Ha.						
Halloysite (?) ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O \cdot Aq.$)	Ha.										Ha.
Unhydrated cpds. of Al_2O_3 & SiO_2 ..											
Cyanite ($Al_2O_3 \cdot SiO_2$)											
Andalusite ($Al_2O_3 \cdot SiO_2$)											
Sillimanite ($Al_2O_3 \cdot SiO_2$)											

	530°C.	620°C.	670-820°C.	700°C.	720°C.	775°C.	800°C.	880°C.	950°C.	1000°C.	1060°C.
Silica.											
Vitreous (SiO_2)											
Ppted. and Soda ($SiO_2 \cdot x\ H_2O + Na_2O$)											
Ppted. ($SiO_2 \cdot 2H_2O$)											
Alumina.											
By calcining Nitrate (Al_2O_3)											He.
Ppted. ($Al_2O_3 \cdot x\ H_2O$)											
Diaspore ($Al_2O_3 \cdot H_2O$)											
Gibbsite ($Al_2O_3 \cdot 3H_2O$)											
Bauxites.											
Red										He.	
Grey									He.		
Clays.											
Kaolin ($Al_2O_3 \cdot 2H_2O$)	S.	S.		S.			S.	S.	S. He.		S.
Farnley	S.							S.	S. He.		S.
Atlas	S.							S.	S. He.		S.
Ayrshire	S.	S.		S.			S.	S.	S. He.	S.	
Ball Clay								S.	S. He.		S (103°C)
Other Hydrated Cpds. of Al_2O_3 & SiO_2											
Pyrophyllite ($Al_2O_3 \cdot 4SiO_2 \cdot H_2O$) ..					Ha.						
Allophane ($Al_2O_3 \cdot SiO_2 \cdot 5H_2O$)			L.					Ha.	He.		
Halloysite (?) ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O \cdot Aq.$)								He.			
Unhydrated Cpds. of Al_2O_3 & SiO_2 ..											
Cyanite ($Al_2O_3 \cdot SiO_2$)						Ha.					
Andalusite ($Al_2O_3 \cdot SiO_2$)											
Sillimanite ($Al_2O_3 \cdot SiO_2$											

S = Shrinkage ; Ha. = heat absorption ; He. = heat evolution ; L. = Loss in weight.

(N.B.—Differential heating curves were taken for the whole of the substances shewn in the table ; loss in weight experiments were done with kaolin, Farnley fireclay, Ayrshire bauxitic clay, diaspore, gibbsite, and allophane ; shrinkage determinations were made on the clays.)

account of the impurities associated with the alumina in combination or some form of solution effective for the purpose.

(*c*) Most of the materials show heat absorptions at temperatures below 500°C., presumably due to the loss of water from colloid substances.

(*d*) The phenomena observed with the clays are not primarily dependent on the presence of silica. They are noticeable with alumina and with a red bauxite practically free from silica, though the heat evolution then took place at a higher temperature.

(*e*) For some reason, although alumina calcined at 700°C. and the bauxites and clays show marked heat evolution at about 1,000°C. as noted above, precipitated alumina gave no sign of it. It may be that the change responsible for the heat evolution had occurred with the precipitated alumina before it was heated in our apparatus, but that with aluminium nitrate, or silicate the presence of the other material associated with the alumina deferred the change.

In accordance with our plan, we do not at this stage attempt a complete explanation of the results obtained, which awaits the further evidence we hope to be forthcoming from other methods of examination which we, and others, are applying.

We have, however, for convenience of comparison, summarised in Table 6 the results obtained for shrinkage, loss in weight, and heat absorption and evolution.

Our thanks are due to Mr. H. C. Versey, M.Sc., and to Mr. F. H. Butler, M.A., for their care in selecting many of the specimens used in this investigation.

XI.—Some Changes taking place in the Low-Temperature Burning of Stourbridge Fire Clays.

By C. E. Moore.

THIS research was originally undertaken to investigate certain sudden contractions observed in Stourbridge clays of widely varying composition. The examination of these contractions, which took place at certain definite "critical temperatures," and of changes in other properties occurring simultaneously with the contractions, seemed to give some useful information as to the composition of the prevailing form of "Clay Substance." The research thus deals largely with the explanation of the changes in properties observed and the interpretation of these changes in the light of the various theories extant as to the composition of fire clays. Some descriptions of the effects observed are here given, followed by a discussion of the probable nature of the changes. The results are grouped under the following headings: (i). Contraction ; (ii.) Porosity ; (iii.) Specific Gravity ; (iv.) Hygroscopicity ; (v.) Solubility in acids ; (vi.) Heating curves ; (vii.) Dehydration.

Section I.—Contraction Experiments.

These were undertaken in order to examine the rate of contraction during firing rather more closely than is usually practised. For this purpose the measurements were made during the actual burning process on hot bars and not, as is usually done, on bars cooled to atmospheric temperatures. The apparatus used was as follows :—(*a*) The furnace in which the bars were fired. This was a gas-fired heat treatment furnace by the Incandescent Heat Co., Ltd., of Smethwick. As run on town gas the furnace is capable of attaining a temperarure of 1150°C. The rate of heating is well under control, and the furnace is specially designed to give an even distribution of heat. The temperature does not vary 10°C. over the working portion of the furnace, and over the space actually utilised the differences observed were no more than 3°C.

(*b*) The temperature of the furnace was determined by a Fery radiation pyrometer and Cambridge optical pyrometer; agreement was within 8° and 10°C. as checked by platinum platinum-rhodium thermo couple and milli-voltmeter.

(*c*) *The Clay Test Bars.* These were five centimetres in length and one centimetre square and had one end mushroomed out to 1·5 cms. diameter. All these dimensions are those of bars as moulded. The bars were prepared in wooden moulds, the surfaces being smoothed and trimmed after moulding. The bars were exposed to warm air (about 40°C.) for 12 hours and then heated for one hour in the steam-oven. The length of the bars was then measured with vernier calipers prior to firing.

(*d*) *Contractions. Measuring apparatus.* The bar the contraction of which was to be measured was placed, mushroom end uppermost, in a silica tube 10″ long by $\frac{3}{4}$″ internal diameter. This was inserted through the roof of the heat treatment furnace and rested on firebrick supports. The portion of the tube inside the furnace was 6″ in length so as to allow of even heating of the test bar. Two narrow silica tubes were placed, one inside the wide bore tube and with its end resting on the upper surface of the test bar, and the other outside the tube and with its end resting on the firebrick supports. These two tubes passed through the furnace roof and then through two holes in an iron plate which, while giving them freedom of movement in a vertical direction, prevented any lateral slipping. Attached by spring-clips to the upper ends of the silica tubes 6″ above the furnace roof were two nickel pointers.

By observing the distance between these pointers the changes in length of the bar could be followed. Any movements of the furnace floor, change in length of the firebrick supports, etc., are eliminated from the results, as both pointers are equally affected. The actual quantity measured is, of course, the difference in the expansion of silica and the clay under test.

The measurement of the distance between the pointers. In order to combine a high magnification with a wide field so as to include both pointers, a "Davon" micro-telescope was employed. This was fitted to a sub-stage of a "Beck" microscope. A 1″ objective and 8 x eye piece was used giving a magnification of 46 diameters at 12′. The substage was racked to and from the stage so as to focus the image of the pointers on to the plane of a stage micrometer divided to ·1 and ·01 mm. The instrument was set at such a distance from the furnace (12′) that ·01 mm. on the stage micrometer corresponded to ·3 per cent. on the clay bar (*i.e.*, ·15 mm.). The readings were easily taken to $\frac{1}{4}$ of the ·01 divisions, which is equivalent to ·075 per cent. The usual method of procedure was to adjust the micrometer by a mechanical stage, so that one pointer was kept on a datum line from which the distance was measured.

In the first series the furnace was allowed to heat up rapidly in the early stages and no readings, or very few, were taken below 500°C. Above about 1,080°C. this furnace heated too slowly for curves to be taken and occasionally, owing to low gas pressure, it had to be discontinued at low temperatures. The results of tests for the following clays are here given :—

Geological Survey Analyses.

	Old Mine Black	Old Mine Average	New Mine No.1.	No. IV.
SiO_2	45·22	51·30	58·18	62·67
TiO_2	1·08	On Dry Clay	1·27	1·15
Al_2O_3	31·32		26·36	22·30
Fe_2O_3	1·75	35·08	1·61	2·90
CaO	·34		·29	·23
MnO	·03		·03	·03
MgO	·51		·69	·66
K_2O	·94		1·67	·48
Na_2O	·23		·20	·38
P_2O_5	·07		·12	·07
FeS_2	·01		·04	·02
H_2O 105°C.	3·00	2·95	1·56	1·61
H_2O	11·3	11·35	8·19	7·86
Organic	4·18		·21	·12
CO_2	·04		·01	·04
Loss on Ignition	18·52	13·38	10·17	9·58

Old Mine Average.

Temperature.	Contraction.	Temperature.	Contraction.
110°C.	3·5%	110°C.	3·65%
Up to 550°C.	3·5	Up to 530°C.	3·65
610°C.	3·2	595°C.	3·15
645°C.	3·5	620°C.	3·75
670°C.	3·5	680°C.	3·9
695°C.	3·5	720°C.	4·15
710°C.	3·8	750°C.	4·2
740°C.	4·1	790°C.	4·25
810°C.	4·1	850°C.	4·7
845°C.	4·25	885°C.	4·85
875°C.	4·4	900°C.	5·125
895°C.	4·7	915°C.	5·665
910°C.	5·0	950°C.	5·925
925°C.	5·3	1000°C.	6·55
955°C.	5·45	1020°C.	7·49
970°C.	5·6	1025°C.	8·0
1010°C.	6·2	1040°C.	8·475
1020°C.	6·35	1050°C.	9·0
1030°C.	6°5	1070°C.	9·5
1040°C.	6·8	1080°C.	10·0
1050°C.	7·4		
1055°C.	8·0		
1070°C.	8·3		
1075°C.	8·75		
1085°C.	9°2		
1093°C.	9·5		
1095°C.	9·8		

New Mine No. I.

Temperature.	Contraction.	Temperature.	Contraction.
110°C.	4·2%	110°C.	4·0%
570°C.	4·123	400°C.	3·85
615°C.	4·05	460°C.	3·925
620°C.	4·2	530°C.	3·85
655°C.	4·425	570°C.	3·85
680°C.	4·575	580°C.	4·0
720°C.	4·65	595°C.	4·075
730°C.	4·725	605°C.	4·15
750°C.	4·65	690°C.	4·3
790°C.	4·725	710°C.	4·375
820°C.	4·8	720°C.	4·45
870°C.	4·875	740°C.	4·3
900°C.	5·1	770°C.	4·375
930°C.	6·6	785°C.	4·45
940°C.	6·675	835°C.	4·525
945°C.	6·9	870°C.	4·7
960°C.	6·975	880°C.	5·05
970°C.	7·2	890°C.	5·2
990°C.	7·65	900°C.	5·8
995°C.	7·8	905°C.	6·1
1015°C.	5·4	920°C.	6·25
1020°C.	8·625	950°C.	6·55
1025°C.	9·0	955°C.	6·775
1035°C.	9·45	965°C.	6·85
1038°C.	9·6	970°C.	7·15
1045°C.	9·9	975°C.	7·3
1050°C.	10·05	990°C.	7·675
1055°C.	10·275	1000°C.	8·05
1060°C.	10·5	1015°C.	8·425
		1030°C.	9·1

Old Mine Average Measured Cold.		Old Mine Average Fired to 1140°C. and refired.	
Temperature.	Contraction.	Temperature.	Contraction.
620°C.	4·95%	200°C.	·075%
670°C.	5·05	300°C.	·15
700°C.	5·3	450°C.	·225
730°C.	5·2	510°C.	·3
760°C.	5·2	560°C.	·45
790°C.	5·3	620°C.	·375
840°C.	6·1	700°C.	·375
880°C.	6·8	720°C.	·45
895°C.	7·1	920°C.	·60
915°C.	7·3		
925°C.	7·35		
940°C.	7·40		
950°C.	7·50		
985°C.	7·75		

New Mine No. IV.

Temperature.	Contraction.
110°C.	3·6%
490°C.	3·3
530°C.	3·225
600°C.	3·3
620°C.	3·45
660°C.	3·6
690°C.	3·675
760°C.	3·75
775°C.	3·825
800°C.	3·9
840°C.	4·2
860°C.	4·575
870°C.	5·1
885°C.	5·4
910°C.	5·7
925°C.	5·775
940°C.	6·0
960°C.	6·45
970°C.	6·675
990°C.	7·2
1010°C.	7·35
1020°C.	7·575
1029°C.	7·8
1035°C.	7·375

Old Mine Black Temperature.	Contraction.
110°C.	4·2%
250°C.	4·5
400°C.	4·65
520°C.	4·35
570°C.	4·5
600°C.	4·425
640°C.	4·65
675°C.	4·8
695°C.	5·1
730°C.	5·025
775°C.	5·1
785°C.	5·205
820°C.	5·4
840°C.	5·7
855°C.	6·15
870°C.	6·45
880°C.	6·6
885°C.	6·75
890°C.	6·975
920°C.	7·11
930°C.	7·2

The foregoing results show plainly that certain changes in the shape of the contraction curves take place at approximately the same temperatures in all the clays examined.

The changes observed may be summarised as follows:—

I. *Expansion at* 570°–610°C. (See appendix II).

II. *Contraction followed by re-expansion at* 700°–740°C.

III. *Contraction having a maximum at* 880°–920°C.

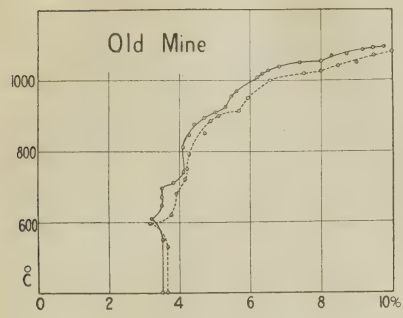
IV. *Contraction at* 1,020°C.–1,030°C., *at* 980°C. (*one case*).

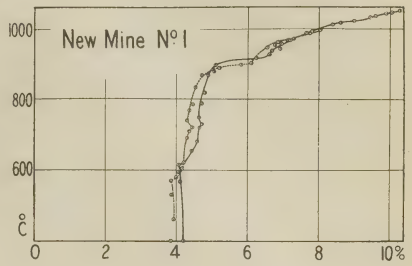
Changes II., III., and IV. will now be considered in some detail.

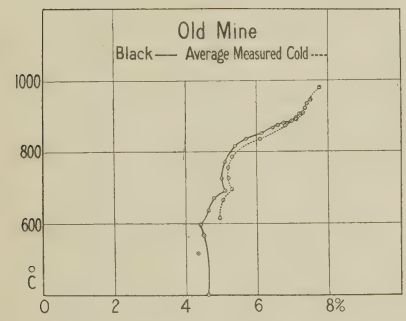
Change No. II. 700°C.: This change is of an abrupt nature and constitutes a sudden contraction with subsequent return to the normal. The temperature at which the change takes place is fairly constant and in most cases the maximum is well-defined.

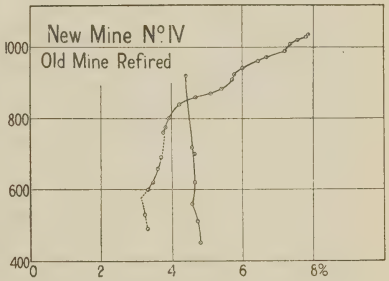
The magnitude of the change diminishes as the alumina-content of the series of clays decreases until in the No. IV. New Mine clay the effect was too slight to be detected by this method.

Change No. III. 900°C.: This change is of a more gradual









nature than No. II., and the maximum is sometimes well defined, sometimes not. The temperature of the change seems to fall slightly (Old Mine average 920°C., New Mine No. 1, 910°C., No. IV. 870°C.) as the clay becomes more siliceous.

The change takes place as the main contraction of the clays is just beginning and for this reason is less well defined than the 700°C. change. The magnitude of the change seems again to vary directly as the alumina content, but the effect is less marked than with No. II. and the old mine black proves an exception.

Change No. IV., 1,030°C. : This change is well-marked although the curve here is rapidly flattening. The decrease in magnitude and the lower temperature are strongly marked as the alumina percentage drops.

Let us now consider changes II. and III. at greater length.

The changes are real contractions and not merely changes in the coefficient of expansion, as is shown by the old mine contraction curve based on bars measured cold. They are also apparently irreversible on cooling as is shown by the expansion curve of the refired old mine.

The effect of these changes on some other physical properties will now be given.

Section II.—Porosity.

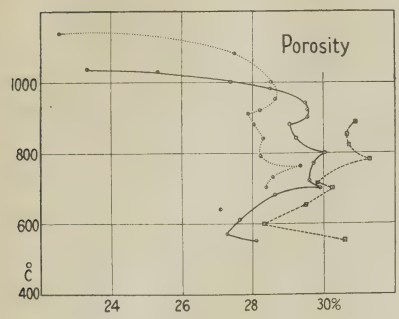
A number of determinations by the "boiling" method were made on spheres of clay of about 1 to 1·5 cms. diameter. The boiling was continued for four hours, it being found that a shorter period gave imperfect expulsion of air. The results by this method are given below:

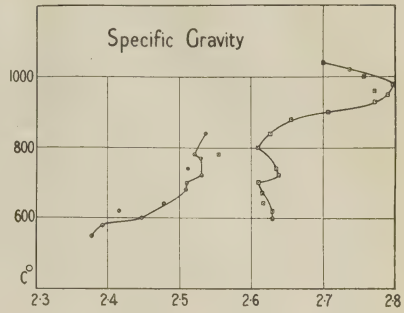
700°C.	28·35%	1000°C.	28·50%			550°C.	28·07%
730°C.	28·53	1080°C.	27·55			570°C.	27·24
760°C.	29·33	1140°C.	22·48			610°C.	27·61
790°C.	28·20			980°C.	28·49%	640°C.	27·05
840°C.	28·28			1000°C.	27·34	680°C.	28·63
880°C	28·01			1030°C.	25·31	700°C.	29·91
910°C.	27·86			1040°C.	23·28	720°C.	28·60
920°C.	28·20			1080°C.	21·41	770°C.	29·73
950°C.	28·62					800°C.	29·22
						920°C.	29·56
						940°C.	29·51

The foregoing results, from experiments on Old Mine clay, indicate: (i.) A decrease in porosity at 600°C.; (ii.) An increase at 800°C.–760°C. followed by reversal; (iii.) A decrease at 880–910°C. followed by reversal; (iv.) A slight reversible increase at 700°C.

The measurement of porosity by this method has been shown by Washburn to be affected with several errors: loss of material by attrition in boiling; loss of soluble salts in boiling; gain in weight due to rehydration.

The porosities are therefore calculated with "weight of clay after boiling and drying" as "Dry Weight." Even with this precaution the results are imperfect when viewed from the standpoint of absolute accuracy, although the relative accuracy is considerably above that required in a demonstration of changes of such magnitude. The presence of "closed pores" to which the water is unable to gain access and the errors due to the film of water on the surface and its removal have been quoted as reasons for rejecting these results. Since, however, the curves show repetitions of the observed effects and since, as the results cannot be calculated while performing the weighings, the "personal factor" is not introduced, the author's claim that the results are truly indicative of changes taking place is not affected. Even if these results were abandoned the effect on the general conclusions, supported as they are by so great an amount of other evidence, would be negligible.





Section III.—Specific Gravity.

This was determined on the powdered clay, fired to various temperatures, by the bottle method. The results given below for Old Mine, specially selected black, and for average Old Mine show a distinct increase in specific gravity at 700°C. followed by a reversion to the normal at 780–800°C. At 880–900°C. the curve flattens appreciably, but no sudden change is shown. At 980-1,020°C. a strong decrease. The difference in values in the two curves is due to the larger proportion of carbonaceous matter in the black clay which both lowers the specific gravity directly and increases the porosity of the grains of clay when burnt.

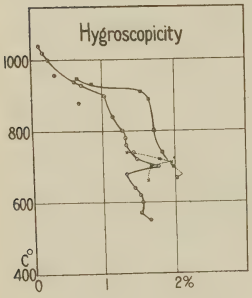
Black Clay.		Average Old Mine.			
550°C.	2·376	600°C.	2·628	930°C.	2·772
580°C.	2·391	620°C.	2·628	950°C.	2·790
600°C.	2·447	640°C.	2·615	960°C.	2·772
620°C.	2·415	670°C.	2·614	980°C.	2·7975
640°C.	2·477	700°C.	2·609	1000°C.	2·756
680°C.	2·508	720°C.	2·637	1020°C.	2·736
700°C.	2·509	760°C.	2·634	1040°C.	2·700
720°C.	2·530	780°C.	2·553		
740°C.	2·511 ?	800°C.	2·608		
770°C.	2·529	840°C.	2·625		
780°C.	2·520	880°C.	2·654		
840°C.	2·536	900°C.	2·706		

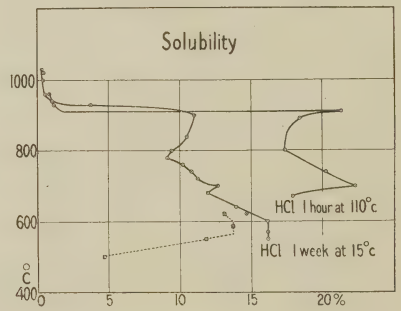
Section IV.—Hygroscopicity.

Mellor determined the hygroscopicity of china clay by exposing weighed samples to a moist atmosphere. By this method both water and gases are absorbed and, as the material is weighed after exposure and the difference in weight taken as hygroscopicity, the result includes both these factors. In order to eliminate the effect of gases as far as possible the following method, a form of

Mellor's experiment with slight modification, was employed. The powdered clay, after having been fired, is exposed to a moist atmosphere for 24 hours by standing over 10% sulphuric acid. It is then weighed, heated for 1 hour to 110°C. and reweighed. The loss of weight is "Hygroscopic Moisture" *and does not include water chemically recombined by a rehydration of the molecule.*

A		B				C	
			On 1 gram raw clay :—				
670°C.	2·15%	550°C.	1·64%	780°C.	1·31%	660°C.	1·62%
700°C.	1·98	570°C.	1·52	800°C.	1·27	700°C.	1·66
740°C.	1·82	600°C.	1·55	840°C.	1·13	710°C.	1·96
800°C.	1·70	620°C.	1·52	900°C.	1·02	720°C.	1·78
890°C.	1·64	640°C.	1·44	930°C.	·70	740°C.	1·32
910°C.	1·63	680°C.	1·33	940°C.	·61		
930°C.	·84	700°C.	1·77	960°C.	·33		
960°C.	·64	720°C.	1·47	1000°C.	·24		
		740°C.	1·42	1020°C.	·16		
		760°C.	1·32	1030°C.	·11		





Section V.—Solubility in Acids.

Two methods of measuring this were used: (i.) Heating with hydrochloric acid for 1 hour at 100°C.–110°C.; (ii.) Treatment with hydrochloric acid at room temperature for one week.

A		B			
670°C.	17·9 %	550°C.	16·20%	780°C.	9·16 %
700°C.	22·31	570°C.	16·16	800°C.	9·41
740°C.	20·26	600°C.	16·19	840°C.	10·51
800°C.	17·38	620°C.	14·69	900°C.	11·06
890°C.	18·45	640°C.	13·91	930°C.	3·755
910°C.	21·35	680°C.	11·93	940°C.	1·025
930°C.	1·15	700°C.	12·67	960°C.	·575
960°C.	·87	720°C.	11·25	1000°C.	·405
		740°C.	10·81	1020°C.	·445
		760°C.	10·21	1030°C.	·305

In both sets of experiments 10 cc. of hydrochloric acid were used per gram of clay. Both curves show similar features: (i.) A sharp increase in solubility at 700°C. followed by a reversion to the normal; (ii.) A gradual increase in solubility commencing at

860°C. in curve I. and at 780°C. in curve II. and continuing up to 910°C. ; (iii.) A very sharp decrease at 900°–930°C.

Both alumina and ferric oxide are reckoned as "soluble matter." Silica as silicic acid was present in the solution in small quantities only and is also included in "soluble matter."

The action of acids on clay is probably of a most complex nature owing to formation of films of silicic acid retarding attack, formation of addition compounds, splitting up of complex silicates, interaction with decomposition products and solvent action of acid on impurities present such as limonite, felspar, etc. Despite these interferences the curves are smooth and without serious discrepancies.

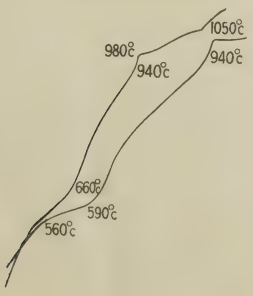
A brief summary may now be given correlating the contraction curves from which the work originated with the four properties since investigated :

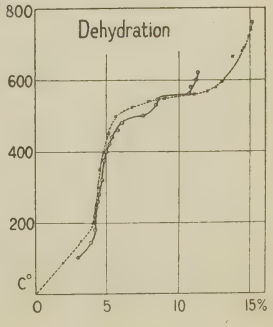
Temp.	Contraction	Porosity.	Specific Gravity.	Hygroscop.	Solubility
570° }			?		change in
610 }	—	—			direction.
700 }	+	+	+	+	+
740 }	—	—	—	—	—
880 }	+	—	+	—	—
920 }		+			
1020	+	—	—	No marked change.	

Section VI.—Heating Curves.

These were taken on about 100 grams of clay heated in a platinum-wound Heraeus furnace. The highest temperature attained was 1,130°C. The instruments used comprised a platinum platinum-rhodium couple, mirror galvanometer and potentiometer balance. The effects observed were :—(i.) Absorption of heat at 110°–120°C. ; (ii.) Absorption of heat at 560°–570°C. ; (iii.) Evolution of heat commencing at 930°C. ; (iv.) Slight absorption at about 1,050°C. No distinct change at 700°C. is observed, but the direction of the curve changes slightly at 745°–780°C. The absorption of heat at 560°C. would, at first sight, appear to give definite proof of the presence of kaolinite or clayite. That this is not so is shown in the next section.

Heating Curves.





Section VII.—Dehydration.

The loss of combined water on heating has been a subject of dispute for many years. This is particularly so with regard to the china clays. It has been stated that water is lost gradually or in one or two stages. In order to follow the process of dehydration a sample of clay was fired in a silica tube contained in a platinum-wound Heraeus furnace. A current of dry air was passed through the tube and over calcium chloride to absorb the moisture given off by the clay. This was determined at frequent intervals by weighing the removable calcium chloride tubes. The temperatures were determined with a nickel-chromium nickel-copper couple and millivoltmeter calibrated against tin, lead, zinc and aluminium.

105°C.	2·96%	440°C.	5·35%	Average rate of heating 2·5°C. per minute.
145°C.	3·88	460°C.	5·78	
180°C.	4·16	480°C.	6·04	
220°C.	4·18	500°C.	7·52	
245°C.	4·26	530°C.	8·41	
260°C.	4·36	545°C.	8·51	
280°C.	4·44	560°C.	10·75	
320°C.	4·66	580°C.	10·85	
375°C.	4·80	600°C.	11·23	
400°C.	4·95	620°C.	11·35	
420°C	5·18			

90°C.	1·89	525°C.	6·73	680°C.	14·58%
150°C.	3·19	540°C.	7·87	720°C.	14·92
200°C.	4·05	550°C.	9·01	740°C.	15·02
250°C.	4·22	560°C.	11·07	760°C.	15·16
300°C.	4·36	570°C.	12·01	Average rate of heating, 2°C. per minute.	
350°C.	4·50	580°C.	12·60		
400°C.	4·72	595°C.	13·04		
450°C.	5·05	665°C.	13·78		
500°C.	5·59	680°C.	14·46		

Both curves show that a distinct loss of water takes place at somewhat similar temperatures to that of the arrest on the heating curve. Mellor, in rejecting the hypothesis that kaolinite at 500°C. loses water to form an anhydride, claims that no sudden loss of water is observed. His dehydration experiments, however, cannot be correlated with his heating curve, as they were affected by conditions of time not present in the latter. By giving an hour's heating at varying temperatures a smooth curve is obtained showing no sudden loss of water. When taking a heating curve, which is completed in 30 minutes, the effect of time on the dehydration action is only slight.

Under these conditions the combined water, which with slow heating is gradually evolved between 400° and 500°C. is retained to 500°C. (the temperature of the arrest on the heating curve) which constitutes an upper critical temperature above which combined water is not found. The water is thus evolved suddenly giving a strong absorption of heat. With the Stourbridge Old Mine clay the water is lost at 500°C.–560°C. with slow heating. When the rate of heating is high, as in the heating curves given, the water is retained to 560°C. and suddenly evolved. *The presence of the arrest on the heating-curve at* 560°C. *is therefore no proof of the presence of kaolinite.*

Explanation according to the Kaolinite Theory.

In reading this explanation it must be remembered that the author only gives his own interpretation of the results and that the supporters of this theory may hold views involving other assumptions than those here given. This explanation is, therefore, more strictly "in the light of the Kaolinite Theory as understood by the author." When it is attempted to explain the experimental results by assuming the "critical ranges" to be caused by kaolinite, difficulties are at once encountered.

(I.) *The* 700°C. *Change(s)*. This might be supposed to represent the 500°C. change observed by Mellor, which he also found on heating curves at 600°C. If this is conceded the arrest observed at 560°C. cannot be due to decomposition into free alumina and silica which must take place at 700°C. Unless we assume that the alumina and silica produced by decomposition reunite almost immediately, it is difficult to see why solubility, hygroscopicity, specific gravity, contraction and porosity first increase and then at about 760°C. return to the normal. It might be supposed that the polymerisation of the alumina would account for the diminution of properties as given by Mellor in his "Collected papers" (The constitution of the kaolinite molecule p. 291). "The alumina (*i.e.*, from the nitrate) at 700°C. is changing to the insoluble condition as fast as it can, but its speed of conversion is very much slower than the speed of transformation of the "nascent" alumina just liberated by the decomposing kaolinite." If, however, we agree to this, we have no explanation of the decrease in solubility, hygroscopicity and porosity and the increase in specific gravity at 920°C. which all point to this change being of a polymeric nature. It is highly improbable that alumina would polymerise in two stages, thus both the reversion at 760°C. and the decrease at 920°C. cannot be due to polymerisation.

(II.) *The* 920°C. *Change.* This might be explained as being due to polymerisation of the alumina as given above. No other explanation appears possible unless we assume that kaolinite does not decompose at the lower temperature but is converted to an isomeric form which subsequently polymerises.

(III.) *The* 1,030°C. *Change.* This may be due to the commencement of vitrification accompanied by union of adjoining grains. This would explain the drop in porosity, the contraction and the absorption of heat. The increase of specific gravity is also in accordance with this view. The kaolinite theory does not seem capable of affording any satisfactory explanation of the changes observed at 700° and 920°C. particularly if the "decomposition hypothesis" is adhered to. It must be stated, in fairness to the Kaolinite Theory, that if it be assumed with Drs. Asch that an isomeric change takes place at the lowest critical temperature, the explanation might be improved in some respects, although if this were the case the solubility after the 700°C. change had subsided should be higher than that previous to the commencement of the change, an effect that is not born out by results.

Explanation according to the Hexite-Pentite Theory.

The disclaimer preceding the kaolinite explanation applies also to this section. A word as to the probable origin of the Stourbridge fireclays may not be out of place here. According to W. S. Boulton (Trans. **16, 247, 1916-17**): "The commonly accepted view that fireclays are the original soils upon which the coal measure vegetation flourished, and that the iron, lime and alkalis have been extracted as food for the vegetation, needs some modification when we examine a series like that of Stourbridge. Here, at all events, where the clays are of exceptional purity and almost depleted of the plant food, there are practically no vegetable remains in situ in the form of coal. It is, I think, probable that the Stourbridge measures were deposited as sediment under estuarine conditions, the fireclays representing the fine silt or ooze, very slowly but continuously deposited, which may have been derived from the soils of the neighbouring lands and swamps after being deprived of the greater part of their iron, lime and alkalis, probably by many generations of plant growth, but possibly by solution during the long period that elapsed between the derivation of the material from its parent rock and its deposition."

It seems probable, therefore, that the purer clays will consist of an alumino-silicate derived from the surrounding "country rock" of the period, admixed with small quantities of free quartzite, etc.

		Molecular Ratio.	Old Mine Black.
SiO_2	45·22		
TiO_2	1·08	15·25	
Al_2O_3	31·32	6·00	
Fe_2O_3	1·76		
CaO	·34		
MgO	·51	·3456	
MnO	·03		
K_2O	·94		
Na_2O	·23	·2580	
H_2O	11·30	11·82	

It seems probable that such groups as K_2O and Na_2O occupy similar positions in the compound to that occupied by water. To complete 12 $R'_2O \cdot H_2O$ is required ·18 R'_2O leaving ·0780· R'_2O in excess. Combining this with the R″O bases

R″O	·3456	
R′O	·1560	(·0780×2)
	·5016	

The final composition is thus :

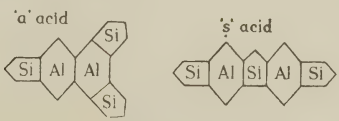
R′O HO 24 (6 Al_2O_3 15 SiO_2) + ·5 R″O 25 SiO

This conception of structure is perfectly feasible, the aluminium and iron probably not occurring together in the same molecule but as separate silicates of the formula 6 R_2O_3 15 SiO_2 12 H_2O.

This would account for the well known appearance of "iron" in Stourbridge fire clays. This takes the form of redish and yellowish grains the centres of which are of a brown or black colour when first brought from the pit, although after weathering the yellow colour penetrates inwards. This would then be due to decomposition of the iron silicate giving haematite (which afterwards becomes limonite) the action being the result of contact with water and carbon dioxide and possibly soluble salts in the mine drainage. Rutile may be formed by the decomposition of the titanate. It is, of course, impossible to decide definitely whether the bases and water form R′O groups in the same or separate molecules and also whether TiO_2 and SiO_2 are associated.

Figures, it is said, can be made to prove anything, but such a correspondence of composition with this simple formula can hardly be a mere coincidence. Two isomeric alumino-silicates are possible of composition

6 Al_2O_3 15 SiO_2 10 H_2O ·Aq.
and 6 Al_2O_3 15 SiO_2 9 H_2O ·Aq.



Since, according to the H.P. theory, this acid and its isomer constitute the basis of the Stourbridge clays, it is necessary to examine its properties as predicted by its structural formulae and compare those properties with those already investigated in the experiments performed on these clays. The properties will be examined under the following headings : (i.) Isomeric Change ; (ii.) Polymerisation ; (iii.) Further changes.

I. *Isomeric Change.* It has been shown that the difference in structural formulae of the two isomers is very marked and a considerable difference in properties might thus be expected.

(*a*) Water Content: The content of combined water, apart from "Water of crystallisation" is in the ratio, "a" acid : "s" acid 10 : 9.

(*b*) The Hygroscopicity also varies in a similar manner, giving a ratio 10 : 9.

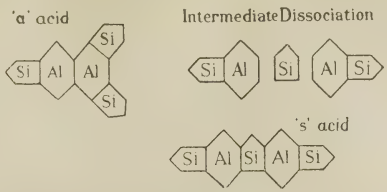
(*c*) Solubility in Acids: This depends on two factors: (i) The resistance offered to the splitting-up of the complex into separate ring-radicles. (ii.) The number of aluminium hexites convertible into pentites without decomposition of the complex. Of these two factors the first exercises a predominating influence on the attack by acids, the second playing a subsidiary part only.

In the "a" acid 6 silicon atoms and 10 aluminium atoms take part in the bonding of the complex. In the "s" acid 8 silicon atoms and 8 aluminium atoms take part in the bonding. The total number of atoms taking part is thus equal in both isomers and no great difference is to be expected, although owing to the strong acidic properties of silicon the "s" acid might be somewhat more resistant.

(*d*) Formation of Salts of the Acids: It is in this direction that the greatest differences would be observed. The process of substitution of OH groups by bases would take a radically different course in the treatment of the two isomers with solutions of alkaline hydroxides, etc. Work on this branch of the subject is proceeding and the result will be communicated later. We thus see that, contrary to what might be supposed, the properties of the two isomers which have so far been measured do not differ to any large extent. We have now to consider a most important matter, the transformation of one isomer into another, a process which involves a *very considerable change in properties*, although the end-products on either side of the transformation are similar in their behaviour.

The Mechanism of the Isomeric Change.

If we consider the method by which one isomer is converted into the other we shall see that, short of actual decomposition into alumina and silica and recombination, a reaction of an unlikely nature and unsupported by experimental evidence, that the change can only take place as follows:



It must be remembered that although, to comply with standard ring formulae, the hexites are shown as having one major axis longer than the two others we have no reason to suppose that they are not perfectly symmetrical and that the six atoms composing the ring are not of exactly similar nature, but possess the same properties. Let us now consider the theoretical effect of a series of transformations as shown above on the properties of a clay. We shall then compare these results with those obtained experimentally and see how far the results agree.

(1) Solubility in Acids and Hygroscopicity : It is obvious from an inspection of the structural formulae that the products formed in dissociation are less firmly bonded together than either of the isomers, the number of silicon atoms taking part in the bonding being 4 and the number of aluminium atoms also being 4. We should thus expect the solubility of the intermediate products to be higher than that of the isomers. We also see that the hygroscopicity must increase, the total number of valencies by which OH groups can be attached having increased by at least 4 (even excluding the silicon ring). The state of division of the clay is also increased owing to the breakdown of crystalline aggregates and thus the adsorption, which is the real hygroscopicity measured in the author's experiments, will also increase accordingly.

(2) Contraction, Specific Gravity and Porosity : The breakdown of the complex into simpler products involves a breakdown of the crystalline form and consequent loss of intra-crystalline rigidity. If the transformation takes place in a substance which is under stress tending to a contraction, as in the case of a clay shrinking owing to loss of water or to coalescing forces, the conversion to the intermediate stage will be marked by a sudden contraction. The formation of the second isomer produces a re-constitution of crystalline form and of intra-crystalline rigidity with accompanying expansion against the forces of coalescence.

The specific gravity will, of course, be affected by this volume change, increasing at first with the contraction and subsequently decreasing. The porosity of the clay when made up into particles consisting of a number of grains with intervening spaces will, at first, increase as each grain diminishes in diameter and so widens

the gap separating it from its neighbours and later decrease again as the expansion forces the grains into closer contact. One cannot fail to see the resemblance between the change in properties caused by an isomeric change as described and that actually observed at the 700°C. critical range.

The following results justify our claim that the 700°C. change is of an isomeric nature with an intermediate dissociation stage and our support of the structural formulae of the Hexite-Pentite theory.

"a" Acid	Temp. at commencement of Change	Decomposition	Middle of Change	"s" Acid	End of Change
Contraction "Normal"	670°C. 5·05%	Increase	700°C. 5·3%	"Normal"	730°C. 5·2% 760°C.
Specific Gravity "Normal"	700°C. 2·609	Increase	720°C. 2·637	"Normal" Different to "a" Acid	780°C. 2·553
Porosity "Normal" ..	700°C. 28·35%	Increase	760°C. 29·33%	"Normal"	790°C. 28·20%
Solubility "Normal" ..	680°C. 11·93%	Increase	700°C. 12·67%	"Normal"	730°C. 11·0%
Hygroscop. "Normal"..	680°C. 1·35%	Increase	700°C. 1·77%	"Normal"	760°C. 1·32%

We now come to the examination of the second set of phenomena derived from the structural formulae, polymerisation and its effects.

II. *Polymerisation.* Of the two isomers the "s" acid only is capable of polymerisation to any extent, and this form must be present before polymerisation takes place on heating. The effects of polymerisation on the physical properties are of a simple nature, and similar to those observed on the polymerisation of other substances such as ferric oxide, alumina, etc.

The chief results of polymerisation: (i.) Increased resistance to chemical attack; (ii.) Lowering of hygroscopicity, both as attached OH molecules and, by binding of material, as adsorbed moisture. ; (iii.) Contraction and increase in specific gravity due to "molecular coalescence." ; (iv.) In a granular material such as clay the contraction might have produced an increase in porosity, but this is apparently counteracted by merging of neighbouring grains.; (v.) Evolution of heat ; (vi.) Formation of larger molecular aggregates possibly causing differences in intra-crystalline cohesion with increase of strength.

The changes taking place at the 920°C. change in the properties so far examined agree well with those theoretically derived from a consideration of polymerisation.

Property.	Theoretical.	Results.		
		880°C.		890°C.
Contraction	Contraction	6·6%		6·975%
		880°C.		910°C.
Specific Gravity	Increase	2·654		2·74%
		840°C.	910°C.	950°C.
Porosity	?	28·28	27·86	28·62%
		900°C.		930°C.
Solubility	Decrease	11·06%		3·755%
		900°C.		930°C.
Hygroscopicity	Decrease	1·02%		·70%
Evolution of Heat		Observed.		

The changes in properties taking place at 920°C. thus bear a very strong resemblance to those of polymerisation. The porosity result is curious, involving as it does a change reversible with increasing temperature, and is not easily explained, but the remainder of the evidence points conclusively to the fact that the change at 920°C. is of a polymeric nature.

III. *Other Changes.*

(*a*) *The* 560°C. *change* is shown in sections VI. and VII. of the experimental results to be due to dehydration of the clay molecule.

(*b*) *The organic matter* is mostly lost at low temperatures, about 550–600°C. providing that an oxidising atmosphere is maintained, but any remaining after this will usually burn off as the porosity increases at the 700°C. critical range unless the rate of heating is high. In the centres of bricks, etc., the carbonaceous material is, of course, liable to be retained to a higher temperature.

(*c*) *The development of the red "iron" colour.* This takes place between 800 and 880°C. when fired at a rate of about 4°C. per minute in an oxidising atmosphere. When observing transparent films of clay during firing in an Heraeus furnace (rate 9°C. per minute), the red colour has been observed to "flash up" rather suddenly at 870°C.

(*d*) *The* 1030°*C. change.* This change, which causes a decrease in porosity and a contraction of fired bars, is probably the commencement of vitrification. The specific gravity of the actual grains of clay decreases, and an absorption of heat is also noticed. Both these facts are in agreement with the view that fusion of some sort is taking place. Whether this fusion is that of the potash and soda aluminosilicates or of the edges of the clay substance grains themselves, cannot definitely be decided. In view of the small temperature range of the transformation the former view seems more probable.

(*e*) Some minor change apparently takes place at about 200°C. on cooling clays which have been heated above

1000°C. Down to 200°C. the clay appears of a greyish-white colour which at this temperature changes to a yellow or yellow-pink. To what this change is due is, so far as the author is aware, unknown and more investigation is needed.

Conclusions.

I. Three definite "critical ranges" are to be found in Stourbridge fireclay at temperatures approximating to 700°C., 920°C. and 1030°C.

II. The changes take place in all the clays of the series and at similar temperatures in each.

III. The magnitude of the changes and particularly of the 700°C. and 900°C. changes decreases with the alumina content.

IV. The examination of the changes in properties at these temperatures gives results inexplicable by the kaolinite theory.

V. The hexite-pentite theory provides a "clay substance" agreeing well with analytical results and with the geology of the deposits.

VI. The transformation of this "clay substance" to an isomeric form gives a complete explanation of the changes in properties at 720°C. and the critical ranges surrounding it.

VII. The polymerisation of the isomer completely explains the 920°C. change with the exception of the porosity results.

VIII. The 1030°C. change is probably of a purely mechanical nature, and requires investigation.

IX. The hexite-pentite theory gives a more complete explanation of the processes involved than any other, and is to be regarded as the most successful theory of "clay substance" in its application to Stourbridge fireclay.

The amount of work to be done on this and kindred subjects is enormous, and no immediate solution of the problems presented can be looked for. It is, however, to be hoped that others will apply similar methods to the examination of clays and that when any further research of this nature is undertaken, no pains will be spared to obtain sufficient numbers of observations separated only by small temperature intervals.

The examination of the changes during firing by means of observations 100 or 150°C. apart is to be most strongly deplored as changes such as these described in this paper may be completely overlooked and definite discouragement laid upon future workers.

In conclusion, the author wishes particularly to thank Prof. T. Turner, principal of the Metallurgical Department, for the kind interest he has throughout taken in the research and for his many useful criticisms.

To the staff of the department and to his fellow students the author is indebted for many useful suggestions and particularly to Mr. E. A. Bolton for thoughtful advice and criticism and for the sympathetic interest which he has always displayed.

Appendix I.

Microscopical Examination.

The 700°C. and 920°C. changes have been investigated by examination of polished surfaces as the cutting of transparent sections from pieces fired to these temperatures is difficult. The 700°C. change shows an opening up of cracks round the grains, but no apparent change in internal structure. The 920°C. change gives little, if any, indication except a tendency for union of neighbouring grains. The 1030°C. change shows a distinct merging of grains and loss of sharp outline.

Thin films of clay on transparent silica plates were examined with the micro-telescope during firing in an Heraeus furnace. Dark lines (fine cracks) opened at 570°C., but closed quickly at 590°C. ($\alpha-\beta$ quartz change). At 700°C. cracks again formed, and occasionally fragments flaked off. No indication of the 920°C. change was obtained. Work at higher magnification and with the aid of polarized light is intended.

Appendix II.

Expansion at 570–610°C.

This is to be ascribed to the joint action of the dehydration of the clay which, as shown later in the paper, takes place at 500°–560°C. and the α–β quartz change at 575°C.

The experimental evidence in connection with this change is as follows :— An increase in length of ·3 per cent., followed by a return to the normal, is observed on heating. On refiring, the magnitude of this expansion is much diminished.

At the same time the specific gravity of the grains of clay increases, and the porosity decreases by an equivalent volume, viz. : 2·3 per cent.

The normal changes taking place at dehydration are as follows : The clay grains shrink owing to loss of water and at the same time the intra-granular porosity is decreased. The surface tension effect between adjacent grains is of sufficient magnitude to prevent separation and thus no increase of inter-granular spaces takes place. The net effect is thus a decrease in volume.

When quartz is present the conditions are at once altered as follows :—While the steam evolved on dehydration will, in the main, escape quietly by the 28 per cent. pore space available as a passage, still a certain amount of local "back-pressure" is set up. This is successfully resisted by the intergranular surface tension.

Should any of the surface tension films include particles of quartz, even of minute size, they will at 575°C., owing to the α–β quartz inversion and expansion, become ruptured. The surface tension forces are immediately decreased to a lower order of magnitude, and the grains are consequently liable to be "blown apart" by the steam pressure.

As soon as the "explosion wave" of steam has passed, the grains will tend to assume their normal positions under the influence of those inter-granular films remaining unbroken.

This explanation completely accounts for the otherwise irreconcilable effects of expansion, decrease of porosity, and increase of specific gravity, and is in accord with the microscopic examination of thin films of clay.

Appendix III.

Future Work.

A few subjects are given here, some of which are at present under investigation, and others which it is hoped to commence shortly.

I. Formation of sodium salts of the isomers and of the intermediate products.

II. Formation of "Ultramarines."

III. Rehydration in its relation to the 700°C. critical range.

IV. Mechanical Tests.

V. Microstructure of films or transparent sections.

JOINT DISCUSSION ON PAPERS IX. X. AND XI.

Dr. Scott:—Although the question of the constitution of clay substance has undergone very considerable investigation in the past few years, our present knowledge of the changes which clay undergoes on heating may be summarized as follows: hygroscopic water is given off endothermically at a temperature in the region of 150°C.; another very definite endothermic change takes place just about 500°C., this change being regarded by Mellor and others as indicating a probable decomposition of the kaolinite or clayite molecule into the three constituent oxides; an exothermic change occurs in the region of 1,000°C., and this has usually been regarded as due to a change in the alumina set free by the 500° reaction. At a temperature somewhat higher than the last mentioned, alumina and silica are supposed to react to form sillimanite, which has been definitely recognised microscopically in fired clays. Within the last few months, several other changes have been described, some on the basis of heating curve arrests, and some based on discontinuities in the temperature curves of various physical properties. In the present paper, the

arrest noted on the heating curves of earlier workers are verified, but the explanations previously advanced, especially in the case of the critical point at 560°, are not adopted. Other critical points are obtained by plotting the variations of porosity, specific gravity, solubility, and so on, against the temperature. In each case the changes, apart from the ones mentioned above, are comparatively slight, and it is very questionable whether such small differences in the case of so inhomogeneous a substance as Stourbridge fireclay are of much value. The number of what might be termed impurities is relatively so large, that some of the effects are very probably due to these impurities.

Again, in some cases, the effects are well within the limit of the experimental error of some of the determinations; in the case of porosity, the maximum variation at any one critical point is of the order of 1 per cent. In the ordinary method of determining porosity, and this method seems to have been used, the unavoidable error is certainly somewhat of the order of 1 per cent., and hence these measurements seem to afford very slight ground for the determination of the critical points. So far as the solubility is concerned, this is bound to be influenced very strongly by two sets of factors. One is the fact that chemically, the clay consists of a heterogeneous mixture of silicates, oxides and so forth; and the other is the great effect of grain size on solubility. The author bases his explanation on the hexite-pentite theory put forward by W. and D. Asch some years ago. This theory was so damagingly criticised on its appearance, that it has generally been regarded as more or less still-born, and the advancement of an explanation of critical points of clay on the basis of this theory seems very much like the resurrection of the dead. There is absolutely no foundation for the complex structures advanced by the authors of the theory either from the chemical point of view or from the physical point of view, and there seems no reason why a 25 or a 35 numbered ring should not be introduced instead of a 5. Hence, there is no reason for dropping the theory put forward by Mellor in favour of the elaborate hexite-pentite alternative. The fact that the water may be given off at temperatures below 500°C. does not vitiate the old theory, as there is no doubt that the kaolinite molecule has an appreciable vapour pressure below 500°C. This has already been demonstrated. The paper by Dr. Mellor and Prof. Bragg, which has just been read (see p. 105), is likewise in favour of the older theory. According to that paper, kaolinite has a definite crystalline structure up to temperatures of at least 500°, while the material which has been heated to a temperature of 700° is apparently amorphous.

The only possibility of such complex structures as those based on the hexite-pentite theory being verified in a clay-heated to 700° would lie in a determination of the crystalline nature of the fired product. The fact that the fired product is

apparently amorphous removes the only proof we might have of a definite chemical compound. So far as the present speaker can say, there is no necessity to vary the generally accepted theory of the structure and break down of clay substance under heat.

The paper by Messrs. Houldsworth and Cobb, on the behaviour of fireclays, etc., under heating is very interesting. The changes obtained are in accord with our present knowledge in so far as they verify the endothermic reactions at 500°, and the exothermic somewhere in the region of 900°. It may also be noted that the 500° change is missing in the case of allophane, but it seems to be obtained in the case of the material called halloysite. It is interesting to note that the change with alumina occurs about 100° higher than the corresponding change in the clays.

Dr. Mellor:—I must confess that I have been surprised at Mr. Moore's advocacy of the Asch hypothesis on the constitution of clays: and I have felt sorry that he has tried to resurrect what I believed to be a dead hypothesis. With all due respect, I cannot see any evidence to justify the exhumation. Far be it from me to hamper our young friend in the choice of hypothesis to explain his work, but it certainly looks as if he has succeeded in obscuring the essentials of some faithful experiments, and in exaggerating the accidentals by a cloud of chemical symbols.

I had a controversy with the Asches in the Transactions of our Society before the War. I purposely took the hypothesis on its strongest, not its weakest lines, and I believed, rightly or wrongly, that I had shown it to be incompatible with facts. As I was asking myself: "Am I mistaken?" I received the current number of the *American Mineralogist*, and there E. T. Wherry (*Amer. Min.*, 7, 116, 1922) says:

> "The structual formula viewpoint would appear to have reached its climax in the monstrous ring formulæ of the Asches, which may be passed over without further consideration."

Let us reduce the hypothesis to its lowest common denominator. Isomeric compounds are invented, dressed up with the properties of clays, and the existence of these properties in clays is employed to demonstrate that these isomeric compounds have a real existence. In one amusing case, Mr. Asch got an erroneous idea that there was a critical point in the heating curve; as a result, his wonderful hexites and pentites gave a perfect explanation of the critical point; but, unfortunately, there was no such point and, therefore, nothing to explain. In the exhumation of the Asch hypothesis, Mr Moore also seems to have overlooked the fact that he is working with a heterogeneous mixture, and not a chemical individual. I place no reliance on any of the proposed silicate formulae; I regard all the different schemes proposed as furnishing systems of classifications—poor ones it is true, but the best we can do until the X-rays or some other agent has revealed the inner structure of the molecules.

Whatever case the Aschs have made out for the tungstate complexes, I think that the extension of their hypothesis to clays, at any rate in their hands, is poor; and when they still further pass to cements and glasses, their application of the hypothesis becomes ludicrous. I will go further and say that Sir William Bragg's and F. Rinne's interpretations of the X-ray diagrams of silica and various silicates is absolutely incompatible with the hexites and pentites; and Mr. Moore's attempt to revive that hypothesis is a waste of time, paper, and ink. If he desires to marry truth, or the nearest approximation to the truth, he must cease flirting with the hexites and pentites, and leave them to rest in the museum of extinct hypotheses.

Mr. Moore says the break at about 500° is not characteristic of kaolinite or clayite. He offers no evidence in support of his contention. Can he tell us what other compounds give the same break ? In making such a statement without adequate evidence, does not Mr. Moore show that he has not grasped what the chemist implies in speaking of "the characteristic reactions of chemical compounds" ?. I should like him to re-consider his remarks on the subject.

So far I have drawn attention only to what seem to be weak spots in his work. As a matter of fact, these weak spots are accidentals, and leave untouched the experimental work. I hope, therefore, that the experimental work will have a fair chance, and not be neglected. I also trust that Mr. Moore will continue making good observations on the properties of clays, which, as he grown in knowledge, he will find to be kittle cattle.

Mr. W. J. Rees:—So far as we can discuss the papers before us, having merely listened to them for the first time, I must say that I agree with what Dr. Scott has said, viz.:—"That the observations made by Mr. Moore do not at all lead one to discard the explanations advanced by Dr. Mellor many years ago." Dr. Scott has already said that the effect of the impurities present in the clay may account for many of the changes in contractions, porosities and so forth, which have been referred to by Mr. Moore.

It is a matter for congratulation that we have a young man following up so earnestly determinations on clays. This is all to the good, even though he may shortly decide to change his views entirely on some of the questions which he has been discussing. I quite agree, from observations that I have made myself, and from the concensus of observations made by other workers, that the hexite-pentite theory is absolutely untenable. The observations of Dr. Mellor and Prof. Bragg have, I think, further discredited this theory.

Prof. Cobb's paper is exceedingly interesting in its confirmaion of results obtained by other workers. I would like to reserve any futher comments until a later stage, so as to give any of the authors an opportunity of replying to one or two of the points

which have been dealt with by Dr. Mellor and Dr. Scott. But I would again like to congratulate Mr. Moore upon the earnestness with which he has obviously pursued his investigations into the Stourbridge fireclays.

Mr. E. A. Coad Pryor:—As I had not seen the papers before I came into the room, I think it is rather unwise to venture on anything in the nature of criticism. It appears to me that, taking the three papers together as a symposium, we have before us a very interesting collection, and it seems a pity that we have not been able to see advance copies of the papers before the meeting; we might then have had a very interesting discussion.

I would like just to ask Mr. Houldsworth if he can give us, when the paper is ultimately published, some information as to the details of the pyrometric work, and especially as to how he managed to manipulate his rise and fall in temperature, and to maintain a sufficiently uniform temperature. It would also be interesting to know the sizes of the specimens that were used.

Dr. Geoffrey Martin:—At first sight, Portland cement does not appear to have much connection with this subject, but when one gets into details one finds that it has a very great connection. Prof. Cobb apologised for introducing some purely theoretical work, and he himself admitted that he was not prepared at this stage to point an immediate practical application of the work involved. Well, one of the reasons why I came up to this meeting was to try to get this practical application.

We are at present engaged in working out the heat balance of the rotary kiln. The work, so far, is very incomplete. A tremendous amount of guess-work is being resorted to, and one of the causes for this is that we do not yet appear to know the amount of heat that is required in order to decompose the clay. I was rather disappointed, therefore, to see that the work, so far, is purely qualitative. No doubt it is extremely difficult work, but I do hope that possibly at some later date, when the experimental methods are more refined, it may be possible to get a quantitative result as to how much heat is absorbed at the various stages.

One method which I have thought about, although I may say that I have not done any practical work on the subject, is this: Why not measure the vapour pressure of the water given off? The increase of the vapour pressure with the temperature would give a method of working out, by thermo dynamics, the heat quantities involved. It is difficult work, I admit, but it seems rather surprising that this has never yet been done, seeing that it is a method that has been known for the past 30 or 40 years.

Another important point from our point of view is the velocity of the changes. I believe velocity does not count in ceramics. You want to get good wares, and to do that you burn more or less slowly. On the contrary, our object in using a rotary kiln is

to get as great a quantity of material through in as short a time as possible. But if you run the material through the kiln too rapidly, what happens ? You do not get the heat penetrating to the core of the material and so what you get as the finished result is more or less unburnt Portland cement. It is quite important, therefore, that we should find out the velocity of these various changes, and ascertain how the changes are affected by these velocities. Work on this phase of the subject would be most useful in getting results in our particular branch of industry, although possibly it would not be of much use to people who are engaged merely in the ceramic industry.

As regards the theories which have been put forward, I think that this new work that Dr. Mellor is now engaged upon in collaboration with Prof. Bragg, will conclusively settle once and for all the hexite-pentite theory. I have no doubt that within a few years from now, we shall have complete data on the subject, and therefore, it does not seem worth while discussing the subject at the moment. It will be better to wait until the experiments, now in progress, have been completed.

There is just another point which is interesting to us. In the testing of refractory materials, the tests are usually carried out in a muffle furnace. Now for our own particular work—Portland cement—the velocity of the gases running through the kiln has a very great effect on the rate at which the lining wears out. Has any work yet been done correlating the speed of the gases passing through a tube lined with refractory material and the rate of decomposition of the clay or the wearing out of the refractory materials under these conditions ? In one case, if the gases flow through quite slowly, a lining may last many months, but if the velocity of the gases is permitted to increase, the kiln will be burnt out within a few days. This is rather an important point, on which I have not yet seen anything published in the literature relating to cement manufacture.

Dr. Mellor:—What amount of dust is there in the gas ?

Dr. Martin:—There is a fair amount.

Dr. Mellor:—There has been quite a lot of work done on the subject.

Dr. Martin:—If that is so, I would very much like to get references to it. We are at Gravesend, and we are rather cut off from what is being done experimentally. If any one can give me information on the subject, I should be very glad.

I would like to congratulate the authors upon the very valuable work that has been done. There seems to be every reason to believe that within a few years, at the present rate of investigation, the whole subject of clay will stand on very different ground.

Mr. R. S. Frink:—I have listened with interest to the three

valuable and instructive papers and the theories which have been presented by the authors, and I hope they will bear fruit and be proven, especially the Hexite-pentite theory, so ably expounded by Mr. Moore. However, it occurs to me that whereas all have dealt with causes for various reversion phenomena, showing with extreme accuracy many factors to be considered and, rightly or otherwise, ascribing the functions of some of the factors and components of clays, I have yet to hear anything, either theory or fact, relating to the part played by, or the effect of water upon the mineral constituents of clay at the temperatures and under the conditions recited in these papers. May I, therefore, offer the suggestion that the functions of H_2O at the temperatures used, *i.e.*, at 300—960°, are worthy of greater consideration than to regard the water as something to be got out of the way—excess baggage as it were—and that possibly it is a most potent factor in affecting the values expressing expansion, solubility, strength, volume, shrinkage, reversion, density, apparent refractoriness and resistance to attack by glass, etc.

My suggestion arises out of considering a few facts which may be known to all of you, viz., that silica brought into contact with superheated steam at temperatures ranging from 140—230°C. is attacked by it, forming some compound, possibly silicon hydride or hydroxide, SiH or SiO.H under which condition water or silica, as also many other substances with H_2O, is extremely active and forms true or pseudo compounds as in the sand lime brick process, the Kayser process of extracting alumina and alkalies, and in the excessive volatilization of SiO_2 in a tank furnace if the gas is very wet.

Some years ago, I investigated this phenomenon in a crude way. In firing certain clay vessels made to contain refined molten glass, one lot was fired with long water smoking, say 4—5 days at from atmospheric temperature to 200°C. Another lot, made from precisely the same clay mixture, took from $1\frac{1}{2}$—2 days to attain the same temperature, after which steam was introduced into the fire which entered the kiln until a temperature of 500°C. was reached. It was then found that the strength of the vessels and their resistance to glass attack were greatly increased, that is to say, where these vessels used to have a life of from one to two days, after burning in the second manner the life was increased to from three to four weeks.

I will not now attempt to impose upon you my theory of what occurs, for I feel that there are already sufficient theories awaiting proof before one is safe in adopting them, but I strongly feel that in all of these papers two very important and effective elements have been ignored. The presence of H and O in the kiln or within the clay body under the conditions stated, may be not only useful but positively necessary to the production of a material we are so urgently requiring, if and when we understand how to control and apply their functions.

Lt.-Col. Thomas:—One thing which has arisen out of this discussion is, that the ultimate result of the work which has been brought before us this morning should be of great value in considering the firing of fireclay materials. Dr. Martin made some references to the quantitative aspect of the heating of clays, and I believe—if I am mistaken, Dr. Mellor will correct me—that the Research Association has something of this sort on its programme for the future. Exactly when we shall reach that stage I do not quite know. But it seems to me to be a point of sufficient importance to be considered, and possibly, Dr. Martin's Association will be disposed to confer with the Refractories Research Association in pursuing the subject. The time required for burning is, of course, of very great importance to the fireclay industry, as well as to the ceramic industry in general, and it is a point that I myself brought forward some little time ago, when I emphasised the importance of considering the changes which occur both on drying and on burning. The drying is already under investigation, and I hope the burning will follow at no very distant date.

Mr. Houldsworth:—We are hoping to investigate shortly any changes of refractive indices and specific gravity which may be associated with the other changes we have found on heating clays, etc. We have appreciated already the importance of the point Dr. Scott mentioned as to the determination of the shrinkage of pure amorphous silica and alumina, but we have not been able to overcome the difficulties inherent to such an experiment. The contraction experiments were carried out on specimens 20 cms. long, and if one starts with precipitated silica or precipitated alumina, one cannot get the specimen into a form suitable for use in the apparatus without the aid of a binder, and once that is introduced in sufficient quantity to give a strong test-piece, it is likely to modify considerably the whole of the results. It would be most useful to have the shrinkage data for alumina and silica, but the present method does not lend itself to such an investigation.

Mr. Coad Pryor asked for information as to the rate of heating of the furnace in the different experiments. The specimens were heated at about 8°C. per minute in the majority of the experiments, but we have taken the temperature up at rates of from 7—12°C. per minute without finding the transformation points affected more than 10°C. by these alterations.

Dr. Martin's points were very interesting, particularly to one who is not conversant with the practical side of the Portland cement industry. We should like to obtain quantitative data for the heat changes occurring at the various points, but we have not been able yet to evolve any satisfactory method of doing this. However, in view of what Dr. Martin has said as to the practical importance of this subject, we will reconsider this matter.

We were very much interested to find that Prof. Bragg and

Dr. Mellor were associated in a paper on the X-ray analysis of kaolinite. After we found that the shrinkage of kaolin took place in stages, we felt that the only way of settling the physical changes that might be involved was by X-ray analysis. But Universities are not blessed with large funds at the present time and the cost of the apparatus was prohibitive. It is work which opens out a wide field in the investigation of the changes taking place in refractory materials on heating.

I read the pre-print of Mr. Moore's paper with particular interest, because he has been working on very similar lines to those of Prof. Cobb and myself. I think in view of the experiments which Mr. Moore has described, it is somewhat regrettable that the manuscript of our work dealing with shrinkages and loss in weight of clays was not ready in time for pre-prints to be before you. Mr. Moore has described quite lucidly the difficulties inherent to investigations of this nature. We have not tested any Stourbridge clays, but we have examined the shrinkages of kaolin, Dorset ball clay, Farnley and Atlas fireclays and an Ayrshire bauxitic clay, and it is remarkable to see how the shrinkage points of the different clays agree to within 10 or 20 degrees.

I should like to ask Mr. Moore how long the specimens he examined were heated before their porosities and specific gravities were determined, and to remind him of the work carried out in America in 1910 by Knote, who determined the changes in the specific gravity of certain American clays, after heating. Knote found that the specific gravity was lowered after heating at 500°C. and that subsequently it only increased appreciably at about 950°, where a sudden increase took place. He found no distinct increase in specific gravity, such as Mr. Moore describes in connection with the Old Mine clay at about 700°C. Our own experiments on this point are not yet complete. The rapid increase in specific gravity which Knote found at 950°C. corresponds with the rapid shrinkage of the clay at that temperature and also with the heat evolution which so many observers have noted at that point.

Mr. C. E. Moore:—With regard to the influence of impurities, as mentioned by Dr. Scott, this is, of course, extremely important. Possibly in the paper I did not emphasize the importance of these impurities sufficiently, and before we can definitely assert that the impurities have nothing to do with it, we shall, of course, have to prepare a pure clay substance. It would be interesting if we could discover the form in which these impurities are present, and then examine each separate mineral. We could then say how far the transition points were due to the impurities. With the considerable variations which occur in the amount of the impurities, I hardly think they can account for all the changes that were observed, and I also do not think that they would produce changes of such magnitude, particularly the changes in

solubility. However, this is a point that has not yet been definitely settled. I was very interested in Dr. Mellor's X-radiogram, and I hope we shall be able to get similar X-radiograms after the clay has been heated above, as well as below, the temperature at which the changes take place. I would like to ask whether Dr. Mellor intends to have these X-radiograms made also after heating to higher temperatures, as mentioned by Mr. Houldsworth, say to 800 degs. It is just possible that the loss of the crystalline form may be restored at higher temperatures.

With regard to the loss of crystal structure at 500°C., it seems to me that, until we know the actual size of the ultimate crystal unit and the number of molecules composing it, we cannot say that the X-ray spectrograms show definitely the decomposition into free Al_2O_3 and SiO_2 rather than dehydration, as the only effect demonstrated is a loss of crystalline form, which might be due to either of these causes.

We also cannot show that the hexite-pentite structure does, or does not exist, unless we can show the number of molecules in the space lattice and their arrangement within it.

Mr. Houldsworth inquired concerning the firing of the specific gravity and porosity samples. This was carried out in a gas-furnace, the temperature being gradually raised and the pieces withdrawn slowly so as to prevent sudden cooling. In no case were the samples maintained at the temperatures indicated. The reactions taking place were thus not allowed to proceed to completion, and this is, I think, the explanation of the suddenness of the changes observed. The substance is heated above the true change point, and becomes unstable, the change then taking place rapidly.

The following reply was communicated by Mr. MOORE:—

Dr. Mellor has visited upon me all the sins of the H.P. theory, so that I feel some repetition and extension of the disclaimer, which I made in my paper, to be necessary.

I do not attempt to support the whole of the Asch hypotheses, which in several particulars appear untenable, but merely put forward the suggestion that the "clay substance" of Stourbridge fireclays is constituted on H.P. lines, and in undergoing definite changes, dehydration, isomeric change and polymerisation, conforms to H.P. structural formulae. No attempt has been made by me to follow the Drs. Asche into the question of the changes taking place at higher temperatures or to endorse their views as to the rôle of complex silicates in glasses.

I have not overlooked the fact that the clay examined contains admixed impurities, but these are present in relatively small quantities and the "heterogeneous mixture," as far as the "clay substance" is concerned, is on the same footing as the H.P. theory; *i.e.*, non proven.

With regard to the changes at 560°C., since the absorption of heat and the loss of water coincide and since any hydrous alumino-silicate, other than those "colloidal alumina-silica mixtures" quoted by Dr. Mellor (TRANS. **16**, 1916-17, "Do Fireclays contain Halloysite or Clayite ?), *may* dehydrate similarly, I think that I was justified in stating that the arrest at 560°C. "is no proof of the presence of kaolinite." It would perhaps have been preferable to have used the words "definite proof" in place of mere "proof."

Dr. Scott states that the H.P. theory possesses "absolutely no foundation." Before accepting this dictum, I should prefer to see an alternative and superior explanation of numerous hitherto inexplicable phenomena cited by the Drs. Asch.

I am still continuing work on this subject, and I hope to be able, in a future paper, to meet some of the criticisms, or, at any rate, to contribute something to our knowledge of clays.

XII.—Silica Bricks for Coke Ovens.

By A. H. Middleton.

I think this subject will provide an interesting discussion, although, up to the present, there has not been built in Great Britain a single battery of coke ovens designed to be worked at temperatures necessitating the use of silica bricks and, so far as I am aware, only one battery has been built for the walls of which silica bricks have been entirely used. I say entirely, as it has been the practice of one of the Coke Oven Construction Companies to use silica bottle bricks in particular parts of the oven walls which they construct.

I should mention here that by a silica brick I mean one made from quartzite or ganister rock containing about 97 per cent. of SiO_2, to which nothing is added except the necessary fluxing or bonding material. I shall refer throughout this paper to the composite bricks which are almost universally used in this country for the construction of coke oven walls and which contain from 77 per cent. to 85 per cent. of SiO_2, as "quartzite bricks."

For the last fifteen years, the use of these quartzite bricks has been so general that they are now—to all intents and purposes—regarded as the only material that could be used, and few, if any, coke oven owners, builders or managers, have during this period considered any alternative material. The only question they have had to decide has been the particular firm from whom they should order the quartzite bricks. I suggest to you now that, in every case where new coke ovens are to be erected or old batteries largely rebuilt, those concerned should, instead of using quartzite bricks as a matter of course, consider, on the merits of each case, whether silica bricks should not be used instead.

That silica bricks have claims to your serious attention will at once be apparent if you contrast our practice in this country with that of America. There, instead of quartzite being universally used and silica not at all, the position is exactly reversed. Silica bricks are used so universally that I believe I am right in saying every battery built in America during the last eight or ten years has been built of this material, and it is doubtful if a single battery is in operation there to-day the walls of which are built of quartzite bricks.

I would say at once that I am not suggesting that you should consider patching and repairing existing quartzite walls with silica. It is only under the following conditions that I recommend for your consideration silica as a substitute for quartzite :—

(1). In the case of new installations.
(2). The renewal of walls where salty coal is used.
(3). Where ordinary coal is used, but the alterations or repairs are so extensive as to make it possible to alter the whole heating arrangement as well as to replace the actual walls.

Except in cases where salty coal is to be used, there may not be much inducement to replace quartzite bricks with silica unless it is intended to operate the ovens at a higher temperature than that at which they are worked at present. It is not within the scope of this paper to go fully into the respective merits of silica and quartzite bricks from every point of view, or to discuss in detail the different methods that have to be employed in building and operating batteries of coke ovens built of these different materials. I shall only have time :—

(1). To point out very briefly some of the advantages of a silica construction.

(2). To go into some detail on one point in which silica bricks differ fundamentally from quartzite bricks, namely, their permanent expansion when heated to temperatures at which ovens built of silica bricks are frequently operated.

(3). In conclusion, to make a few remarks about the raw material and the burning of the bricks, which may be helpful to those of you who may contemplate adopting this material.

The advantages of using silica bricks in place of quartzite for the construction of coke oven walls may be summarised as follows :

(1). Greater output and greater thermal efficiency.
(2). Greater durability under ordinary conditions.
(3). Resistance to corrosion where salty coal is used.
(4). The possibility of varying the heat treatment where different classes of coal have to be employed.

Greater Output and Greater Thermal Efficiency.

I intend to deal with these two distinct advantages, greater output and greater thermal efficiency, together, as I do not propose to go into sufficient detail to attempt to determine what part of the greater output obtained from a silica construction is due to the greater thermal efficiency, and what part of it is due to the higher temperature at which a silica construction enables a battery to be worked, nor to attempt to decide to what extent the larger yield of surplus gas is affected by one or other of these conditions.

It will suffice for the purpose of this paper to call attention to some of the results obtained at American coke oven plants at which the coke oven walls are constructed of silica bricks. Table 1 shows the sizes, output and carbonising period of several typical American installations. Table 2 shows some detail of coke and bye-product yields from American silica brick ovens. Plants marked "A," "B," "C," and "D" in the two tables are the same. These two tables were compiled for another purpose. I have put these identification letters in the two tables so that those of you who wish to do so may compare yields, etc., in Table 2, with the conditions under which they were obtained with regard to the size of oven and time of carbonisation.

TABLE 1.

DIMENSIONS OF VARIOUS COKE OVENS BUILT IN AMERICA.

No. of Plant	Type of Oven	Dimensions of Ovens						Charge of Coal in tons	Burning time in hours
		Length over all	Length Door to Door	Height to Crown	Width				
					Ram Side	Coke Side	Mean		
		Ft. ins.	Ft. ins.	Ft. ins.	Ins.	Ins.	Ins.		
1 (C)	Wilputte ..	—	37 3	10 $5\frac{1}{2}$	$16\frac{1}{2}$	19	$17\frac{3}{4}$	1115	16
2	Do.	39 0	37 0	10 $8\frac{3}{8}$	15	17	16	10175	$15\frac{1}{2}$
3	Semet Solvay ..	—	36 0	12 0	$18\frac{1}{2}$	$20\frac{1}{2}$	$19\frac{1}{2}$	1315	18
4 (B)	Do. .. .	—	35 0	12 0	$18\frac{1}{2}$	$20\frac{1}{2}$	$19\frac{1}{2}$	1315	18
5	Koppers	—	35 0	8 8	17	21	19	915	$17\frac{1}{2}$
6 (D)	Do.	—	37 9	10 0	$18\frac{1}{2}$	21	$19\frac{3}{4}$	1215	18
7	Do.	40 0	37 6	10 0	$15\frac{3}{4}$	$18\frac{1}{4}$	17	11125	18
8 (A)	Do.	—	37 0	9 10	17	$19\frac{1}{2}$	$18\frac{1}{4}$	1210	19

TABLE 2.

PARTICULARS RE YIELDS OF BYE PRODUCTS, &c.

Plants	Volatile Matter in Coal	Coke Yield	Gas		Sulphate per gross ton	Tar per gross ton	Crude Benzol per gross ton	Coking Temperature
			Surplus	Fuel				
	%	%	%	%	lbs.	Imper. Galls.	Imper. Galls.	
A.	34·75	74·00	57·00	43·00	31	11·2	3·38	—
B.	—	75·00	58·00	42·00	24	7·47	2·7	—
C.	31·00	75·00	60·00	40·00	28·6	11·48	—	1260/1320 C.
D.	32/33·00	—	53/55	47/45	28·00	7·0	*1·7	1343/1371 C. 18 hours coking

*Low yield due to the fact that the whole of the benzol is not extracted, as the whole of the surplus gas is used for towns lighting and must be kept up to 600 B.T.U.

If you compare the results shown in these tables with results obtained on batteries with which you are familiar, it will be apparent that after making due allowance for the decreased width of the ovens, a silica construction makes possible a very much greater output for a coke oven of given size. This is due chiefly to the higher temperatures at which it is possible to work ovens built of silica bricks, but the question of the higher conductivity of silica bricks at high temperatures must not be disregarded, as there is considerable evidence that it is partly responsible for the improved results obtained. Ovens of silica construction may be regularly worked without risk to the walls, at a temperature of from 1,300°C. to 1,400°C., which is from 200°C. to 250°C. higher than it is desirable to go with quartzite bricks, and this implies that the bricks must not fail at a temperature of from 1,500°C.—1,600°C., as peak temperatures as high as this are liable to occur.

Whilst it is doubtful if silica bricks are much better conductors of heat than quartzite bricks at temperatures below 1,000°C., there is, I think, very little doubt that at higher temperatures their conductivity is considerably greater. This appears to be borne out by results which I obtained at one of the American plants, which I visited last year, as the increased temperature alone would not account for the greatly reduced coking time. Owing to shortage of coal, the carbonising period at those works had to be increased, first, from 15½ hours to 18 hours, and, later, from 18 hours to 24 hours. The temperatures which I give below may be relied upon as being correct. They were taken with great care with an optical pyrometer, readings being taken in a number of ovens at four different points in the length of each wall and the results averaged.

The ovens are 15″ wide at the ram side, and 17″ wide at the coke side. The average temperatures for the various carbonising times are :—

Temperature.	Carbonising time—hours.
1,320°C.	15½
1,252°C.	18
1,122°C.	24

You will observe that for an increase of 200°C. above 1,120°C. there is a reduction in carbonising time of 8½ hours. Putting it another way, the output of a silica brick oven worked at 1,320°C. is over 50 per cent. greater than the same oven worked at 1,120°C.

In this connection it will be interesting to quote from a paper recently read by the manager of a coke oven plant in Germany at a conference of German coke oven managers. I refer to the paper by Dr. Enzenauer, which was published in *Stahl und Eisen*, October 7th, 1920. The author is speaking of coke ovens built of silica and quartzite respectively, working side by side with the same class of coal, and gives the following data :—

Coking time of silica brick ovens	..	..	24 hours
Coking time of quartzite ovens	..	..	29 ,,

Temperature of burnt gas in horizontal flue of silica oven	1069°C.
Temperature of burnt gas in horizontal flue of quartzite oven	1,027°C.
Temperature in silica oven at end of coking period	908°C.
Temperature in quartzite oven at end of coking period	804°C.

There is some evidence in these figures that silica is a better conductor of heat than quartzite and that, when worked at the same temperature, an oven built of silica bricks burns off in a shorter time than one built of quartzite bricks.

The author goes on to say: "In consequence of the favourable results obtained with silica brick from all points of view, I think I am correct in saying that the use of silica bricks for the construction of coke ovens must become general."

Effect of Higher Temperatures on Yield of Bye-Products.

Most English coke oven people will naturally be inclined to consider that this greater output of coke from ovens built of silica bricks is only obtained at a sacrifice of bye-products, but I am strongly inclined to think that this is not the case. It is impossible to make a direct comparison between the yields under English and American conditions, as different classes of coal are used at the different plants, but, generally speaking, the yields of bye products, as shown in Table 2, are as high as would be obtained in England under English conditions with similar classes of coal. The explanation of these good yields of bye-products, in spite of the high temperatures at which the ovens are worked, is to be attributed to the fact that the American ovens are so constructed that little decomposition takes place in the tops of the ovens. This question of the top heats was dealt with at some length in the paper which I read before you last session, so I do not propose to say anything further on the subject to-day.

Greater Durability under Ordinary Conditions :—

I cannot put much direct evidence before you in support of this opinion, but it is the conclusion to which I came after examining a number of silica walls in America which had been in operation for various periods at high temperatures, and comparing them with what I know of quartzite walls in this country. One of the American batteries of silica brick ovens that I visited in May, 1920, was built in September, 1908, and had not been repaired in any way. Not only has this silica brick battery of ovens remained in good condition for twelve years, but you must understand that the carbonising period at this plant is 17½ hours. The ovens have, therefore, been pushed 1·6 times as often as a battery, the carbonising time of which is 28 hours. If we, therefore, increase the length of life of the walls in proportion, this would give us a

little over 19 years instead of 12. What I saw of the silica bricks in stock at American coke works and at the brickworks which I visited, leads me to the same conclusion.

The appearance of the silica bricks which I have brought with me for your inspection to-day will go far to satisfy you that most favourable results may be expected from ovens built of this class of material so far as durability is concerned.

Resistance to Corrosion where Salty Coal is used.

In certain coal fields, there occurs with the coal a considerable amount of sodium chloride. The result of this is a most serious corrosion of the quartzite bricks of which the coke oven walls are built. The life of the walls, in districts where salty coal is used, is rarely more than three years and is sometimes as short as nine months.

The owners of the plants in these districts have rebuilt their coke oven walls at intervals of from nine months to three years, as the case may be, with commendable perseverance, but with a want of resource and enterprise which is not so creditable. I believe that all the trouble and expense, due to this corrosion, would be avoided if the walls were built of silica bricks instead of quartzite. The only battery of ovens in Great Britain which is built of silica bricks, and to which I referred at the beginning of this paper, is situated in one of the districts where salty coal has to be used. The water from the washery at this plant never contains less than ·5 per cent. sodium chloride, and the chlorides in the coal estimated as sodium chloride vary from ·35 to ·5 per cent. The moisture in the coal as charged to the ovens is from 10 to 14·5 per cent., so that you will see that the conditions are such as to provide a severe test for the silica bricks. The ovens are operated at normal English temperatures, say, about 1,100°C. in the side walls.

At this plant, two batteries of coke ovens were working side by side with the same coal and under exactly the same conditions. One battery is built of silica bricks and the other of quartzite bricks. The silica brick battery has lasted for six years, whilst the quartzite battery only lasted from three to nine months before the walls had to be rebuilt. No clearer and more convincing evidence could be cited in favour of silica bricks. The immunity of silica bricks from corrosion was also very strikingly illustrated in some of the ovens of another battery at this plant, which was at first built of quartzite bricks, but when the walls were repaired stretcher bricks made of silica and header bricks made of quartzite were used. After a short time, the quartzite header bricks were again destroyed by the corrosive action of the salt in the coal, whilst the silica stretcher bricks remained quite good. The oven walls presented a most peculiar appearance as a result of this corrosion, the stretcher bricks remaining quite sound, whilst the header bricks—at the time I saw them—projected one inch from the face of the oven. Later, these projecting ends would drop off, leaving a depression in the

oven wall. It soon became impossible to push the ovens owing to this eruption of the face of the oven wall wherever the header bricks appeared.

Equally striking results, showing the superiority of silica bricks over quartzite, where salty coal is used, have been obtained in Germany. In the paper previously referred to, one speaker reports that, of a battery of 70 ovens, 55 were built of quartzite bricks and 15 of silica bricks. At the end of four years the silica brick ovens are in exactly the same condition as when new, whilst the 55 quartzite ovens must be entirely rebuilt. Without hesitation, he says, he draws the conclusion that "ovens not built of silica bricks are condemned to death." Another speaker, at the same conference, referring to his experience in another district, spoke in similar manner of the superiority of silica over quartzite bricks.

I will only refer to one other instance of German practice, as the experience quoted in this case is so strikingly in agreement with that at the English battery previously referred to. In this case, the bottle bricks are made of silica and the stretcher bricks of quartzite. The quartzite bricks were eaten out by the action of the salt and all spalled off, whereas the heads of the bottle bricks made of silica resisted the action of the salt and were intact. The oven walls, in the words of the speaker, finally had the appearance of a nutmeg grater.

Possibility of Varying the Heat Treatment where different Classes of Coal have to be employed.

I am not going to dwell upon the beneficial results that may be obtained in some cases through the ability to vary the temperature of carbonisation to suit different classes of coal, but merely call your attention to the possibility of working over a much wider range of temperatures when oven walls are built of silica than when the walls are built of quartzite. In American ovens built of silica bricks and worked at high temperatures, it has been found possible to make excellent coke from high volatile coal, which would not make a satisfactory coke in ovens worked at temperatures considered normal in this country.

Relative Cost.

Ton for ton, silica bricks cost more than quartzite bricks, due chiefly to the extra fuel cost in manufacturing owing to the much higher temperatures at which the bricks must be burnt. This extra cost, however, is almost exactly balanced by the greater output which it is possible to get from ovens of this construction. In other words, to carbonise a given amount of coal, the greater number of quartzite ovens necessary would cost the same as the smaller number of silica brick ovens.

Permanent Expansion of Silica Bricks.

Silica bricks have one property which is liable to give rise to trouble when they are used for the construction of coke oven walls,

particularly when the ovens are operated at the higher temperatures of the standard coking practice in America. I refer to what is known as the permanent expansion of the bricks. This should give very little trouble at temperatures at which coke ovens are usually operated in England, but where it is proposed to work at temperatures 250°C. to 300°C. higher, very great care must be taken to obtain a brick in which the permanent expansion is low. It is quite possible to do this if sufficient care is exercised in burning the bricks, and, if proper allowances are made in the oven design for the unavoidable expansion, very little trouble need be anticipated even when working at the highest temperatures. If, on the other hand, a brick insufficiently burnt or made from unsuitable material is used, most serious trouble will be experienced owing to the brick expanding when in the oven wall. Sufficient allowance can be made for the expansion of an oven wall built of quartzite bricks by putting wooden washers an inch thick behind the buckstay bolts at each end of the oven. In heating up, the length of the oven only increases by an inch or so, whereas in the case of a silica brick oven the normal increase, under the most favourable conditions, is from 4″—6″ for an oven of the same length but worked at a temperature some 200°C. higher. If badly burnt unsuitable silica bricks were used, this already high expansion might be increased by as much as 6″.

You will readily realise that an expansion of this amount can not be looked after in the oven design, and that nothing would prevent the walls buckling to such an extent that it would be impossible to push coke out of the oven. In order that the reason for the necessity for using properly burnt bricks, made from suitable materials, may be fully realised, it is necessary to consider the peculiar behaviour of silica when heated. This peculiar behaviour of silica also explains the very much greater expansion in the length of the oven wall, when working at the high temperatures standard in America, as compared with the relatively small expansion when working at the lower temperatures standard in England. As the matter is of great importance to those contemplating the use of silica bricks, and is, moreover, one which you have probably not had occasion to study, I now propose to consider the matter in some detail.

Silica occurs in a number of allotropic forms, chief of which are :—

1. Quartz.
2. Cristobalite.
3. Tridymite.

and two of these forms occur in two and one of them in three phases, so that there are no less than seven different crystal modifications of SiO_2, all having different specific gravities.

When quartzite or ganister rock is burnt in the presence of

a flux, as in silica brick making, to temperatures which are high enough to make a satisfactory brick for high temperature coke oven use, varying proportions often pass through the whole of this range of crystal modification. If in burning the brick in the kiln a sufficiently high temperature is not reached, and the bricks so burnt are subsequently used in coke ovens at a higher temperature than was obtained in the kiln, the changes in the silica will take place in the oven instead of in the kiln.

When you consider that this crystal modification of the silica is accompanied by a large change in volume, you will see why it is so imperative that the change should take place in the brick kiln if the bricks are to be used in ovens which are to be operated at high temperatures, such as obtain in America. The matter is not so important if the bricks are to be used in ovens which are only to be operated at temperatures met with in normal English coking practice, as no further conversion would take place at such temperatures than occurred in the kiln if the bricks were burnt at temperatures that should be attained in ordinary silica brickworks practice, say, 1,200°C. to 1,300°C. In silica brick making the conversion of the quartz, which is the high specific gravity form, into cristobalite and tridymite, which are the low specific gravity forms, takes place very slowly below 1,350°C., but at higher temperatures the conversion increases very much as the temperature rises, and at a temperature of 1,500°C. the maximum volume is quickly attained with quartz from many different sources. With some, according to Dr. Mellor's investigations, it is still very slow, even a few degrees below fusion temperatures. Some exceedingly valuable research work has been done on this subject by Professor Le Châtelier, and some most interesting results published in the "Technological Papers of the Bureau of Standards" of the United States Department of Commerce on work done by D. W. Ross. I give below two tables: "A" summarises some of the results determined by C. N. Fenner, of the Geophysical Laboratory of the Carnegie Institute. "B" shows the results of Le Châtelier's experiments on thermal expansion.

These two tables show, in a very clear form, the physical changes which take place when a silica brick is heated. Of these changes, those which have the most important bearing on the subject we are considering at the moment are:—

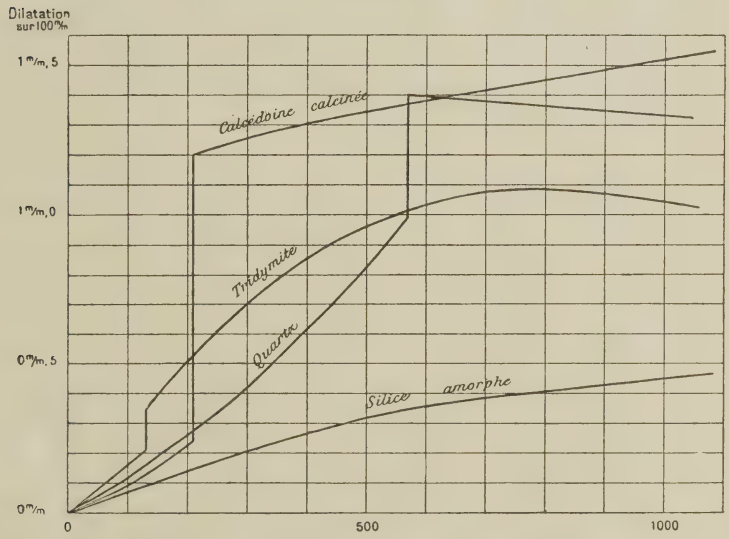
The α cristobalite—β cristobalite inversion which takes place at 220/275°C., and

The α quartz —β quartz inversion at 575°C.

TABLE A.

Inversion.	Temperature.	Remarks.
α quartz–β quartz	575° C.	Rapid reversible.
β quartz–β_2 tridymite	870°C.–10°C.	Very sluggish.
β_2 tridymite–β cristobalite ..	1470°C 10°C.	do.
α tridymite–β_1 tridymite	117° C.	Rapid, reversible.
β_1 tridymite–β_2 tridymite ..	163° C.	do.
α cristobalite–β cristobalite ..	220–275 C.	do.

TABLE B.



Results of Le Châtelier's Experiments in Thermal Expansion.

If you refer to Le Châtelier's chart table "B," you will see how suddenly the volume of the brick increases at these two points. The spalling of silica bricks in a coke oven wall or steel furnace is very largely due to these changes. Badly burnt silica bricks consist almost entirely of quartz. Ordinary well-burnt commercial silica bricks contain a large amount of cristobalite; it is quite possible, however, to burn silica bricks in the kiln in such a way that a large amount of tridymite will be formed. The desirability of having as much as possible of the silica in this latter form for

coke oven purposes will be apparent on examining the curves in Le Châtelier's table. There you will see that, of all the three forms of silica, tridymite is the one which has the least thermal expansion and is least subject to large and sudden increases in volume. It is commercially impracticable to make an all-tridymite brick.

I will close this part of my remarks by quoting the results of a practical experiment I had carried out on some silica bricks in ordinary commercial practice, which very strikingly show the importance of using properly burnt bricks. To make the result of this experiment clear, I will just call your attention to the fact that the specific gravity of quartz is 2·650, of cristobalite 2·333 and of tridymite 2·270, and that these changes of specific gravity are accompanied by a proportionate change in volume. A number of ordinary $9'' \times 4\frac{1}{2}'' \times 3''$ silica bricks were made from the same batch of ground material in the same mould and dried together in the ordinary way. After being dried, they were divided into three lots and set in three different parts of a brick kiln, where it was known that they would be subjected to different temperatures whilst being burnt. A series of seger cones was placed with each lot of bricks. The kiln was fired in the ordinary way, and the results are shown in Table C :—

TABLE C.

	Temp. C.	Length.	Breadth.	Depth.	Specific Gravity.
1	1380	9·225	4·438	3·208	2·43
2	1433	9·250	4·542	3·208	2·35
3	1530	9·350	4·542	3·208	2·28

In order that you may realise the full significance of this difference in burning, you have only to consider that a coke oven wall 38′ $10\frac{1}{2}''$ long, built of the first lot of bricks would, if worked at the high temperatures at which American coke ovens are operated, gradually develop a permanent expansion 6″ greater than a wall of the same length built of the third lot of bricks. You will readily realise that, under such conditions, a wall built of the less highly burned bricks would be completely ruined in a very short time owing to the fact that the expansion in use would be so great that the wall would buckle.

Raw Material.

Ganister or quartzite rock suitable for making first class silica bricks should, generally speaking, contain not less than 97 per cent. of silica and not more than 3 per cent. of iron and alumina together. The total alkalies should not exceed from ·4 to ·5 per cent. The best silica bricks that I have seen were made from rock having the following chemical analysis :—

	per cent.
SiO_2	97·15
Al_2O_3	1·00
Fe_2O_3	1·05
CaO	0·10
MgO	0·25
Alkalies	0·10
	99·65

Samples of this brick are amongst those I am showing you to-day. Raw material cannot, however, be selected on chemical analysis alone. Ganister or quartzite rock of identical analysis with the above may be quite unsuitable for making good bricks.

The physical properties of the rock are equally important. It should be close-grained and hard, or what the quarrymen describe as "strong." On crushing, it should splinter or break into sharp angular fragments. Rocks that powder easily or grind down to round grains without sharp corners do not make strong bricks. On heating to high temperatures, the rock should not crumble or show more than the slightest evidence of cracking. Most of the permanent expansion of the rock should take place on the first heating to a high temperature. One that showed little expansion after the first heating, and continued to expand appreciably after each of several heatings, is unsuitable.[1]

I shall have to hold over my remarks upon brickmaking until some other occasion, as the subject cannot adequately be dealt with in a few remarks, and this paper is already quite long enough. Before closing, however, for the comfort of those who contemplate building coke ovens with silica bricks and working them at high temperatures, I will mention a very interesting fact which has recently been established with regard to the question of burning bricks and quartz conversion, as otherwise you might be under the impression that the risk of using underburnt bricks is so great that no cautious person would be prepared to take it. It has been established that the specific gravity of the brick bears a very definite relation to the quartz conversion which has taken place in the brick and to the temperature at which it has been burned. This specific gravity can be very easily determined by a method described by Le Châtelier so that the amount of expansion which has already taken place in the brick, and the amount which is likely to take place afterwards, can easily be determined and unsuitable material rejected before being put into use. I believe that Dr. Mellor was the first to call attention to the possibility of using this relationship as a useful works guide. I would not advise the use of bricks with a higher specific gravity than 2·35 if they are to be used for ovens which are to be worked at very high temperatures.

[1] Some valuable work on this subject has been carried out by J. Spotts McDowell, of the Harbison Walker Refractories Co., Pittsburg. I would refer those interested to his paper published in "Bulletin No. 119," November, 1916, American Institute of Mining Engineers.

DISCUSSION.

Mr. W. J. Rees:—Mr. Middleton has covered the ground fairly completely in discussing this question of the relative merits of silica bricks and firebricks for the construction of ovens. There are one or two points in connection with the paper which I think require modification and perhaps discussion. When the paper was originally read attention was drawn to the classification of the bricks adopted by Mr. Middleton. It seems to me that if we are to arrive anywhere at all in the discussion of these problems we must have some uniform classification. The classification adopted by Mr. Middleton—one that is used to some extent in America—is an exceedingly confusing one. Here in Great Britain—and I think more or less generally in America and in Germany—a silica brick is considered to be one containing upwards of 92 per cent. of silica. All such bricks are referred to as silica bricks. There should be no attempt to use both "silica" and "quartzite" as descriptions of bricks of essentially different chemical compositions. I suggest that it would be much better to refer to the brick which Mr. Middleton calls a quartzite brick as a "semi-silica" brick or a "clay-silica" brick. We shall then know where we are. I emphasize this point because confusion has already arisen by the adoption of these two terms. I think we should confine the term silica brick to the true silica brick, the intermediate grades can then be termed "semi-silica" or "clay-silica," and we shall understand the true firebrick to be the brick that is made from fireclay.

The question as to which type of brick is to be adopted for the construction of coke ovens will depend, of course, a good deal upon whether the coal which is being coked is dry or wet. It will essentially depend upon the presence or the absence of salt in the coal. I think we are all agreed nowadays that where salty coals have to be coked a silica brick will give a satisfactory result. In my own mind I am pretty confident that no commercially made firebrick will give so high a resistance to the corrosive attack of a salty coal as will a silica brick.

For some time past I have been working upon the question of the corrosive action of salt upon silica bricks, and at some time in the future I hope that the results of this work will be available for discussion. I regret that at the moment I am not able to put them forward.

The type of brick which is to be chosen by the coke-oven manager or builder will depend to some extent upon local conditions. He may be tempted, if he is coking a non-salty coal, to rely as hitherto upon the fireclay brick or upon the semi-silica brick. The point arises as to what advantage he is likely to gain if he adopts American principles and really goes in for a silica bricks. Despite what Mr. Biddulph-Smith says, I think that the higher thermal conductivity or thermal diffusivity of silica brick is a point which counts in the carbonisation of coal. The points which have to be

borne in mind in evaluating a firebrick for the use of coke-ovens are mainly in connection with the volume changes that are likely to occur during the life of the brick. The changes in firebricks are likely to be contractions. The advantages of semi-silica bricks are mainly in the direction of uniformity of volume; at coking temperature any expansion which takes place in the silica part of the brick is more or less neutralised by the tendency to contract in the clay part of the brick. We are more or less satisfied that, with the silica bricks expansions are almost inevitable, but these can be controlled providing that the brick is properly made.

I would here draw aside for a moment in order to refer to the suggested method of evaluating the extent of the conversion of the quartz in a silica brick by means of its specific gravity. There are distinct and definite dangers here. Mr. Middleton does not make any reference in Table C of his paper to the lime content of the bricks which were burned and tested. With a very high-lime brick one will naturally get a somewhat lower specific gravity and I would suggest, therefore, that specific gravity should only be used as a means of evaluating the extent of the quartz conversion where bricks of more or less the same lime content are being compared. Where the lime content is round about 2 per cent. it is possible to compare bricks by determining the true powder density. A brick with 2 per cent. of lime and a powder density of 2·4 will have a higher quartz content than a brick with, say, 2 per cent. of lime and a powder density of 2·3.

It is, of course, obvious to all who have had any experience of the types of silica brick which it is possible to use in the contruction of coke-ovens, that the ordinary type which gives a satisfactory result in steel melting practice will not give a satisfactory result with coke-ovens. The texture of the brick is much more important in coke-oven practice than it is in connection with steel melting or any other metallurgical practice. It is essential that the closest textured brick and a brick of most uniform texture should be used. Spalling troubles are liable to arise when a brick is used with an uneven or a very open texture, and, particularly where wet coals are used, disruption of the brick may occur. Providing, however, a silica brick is employed having a uniform texture and a high quartz conversion, I should not anticipate any troubles in the construction of coke-ovens from silica bricks.

A large number of experiments have been carried out in our laboratories at Sheffield on the relative resistance of various types of bricks to salt corrosion. Throughout the whole of the experiments it has been found that the salt exerts an enormously greater attack upon fireclay and semi-silica bricks than on silica bricks. The experiments have been continued and various other possible impurities in the coal have been considered. One important part of the work is concerned with the action of ammonium chloride on the bricks. Ammonium chloride is, in my opinion, the culprit in

the attack by salty coals. Where salty coals have been in contact with fireclay at low temperatures it is possible to find in the brick ammonium-alumino-silicates. Possibly it is the breakdown at the higher temperatures of these ammonium-alumino-silicates which leads to a good deal of the disruption of the face of the brick. The formation of iron chloride, its passage into the brick and the deposition of a layer of haematite is, of course, another factor.

As I have said previously in a paper on the subject some two years ago, it is possible to compound a firebrick which will resist the attack of the salt in the coal, but the production of such a brick would be exceedingly expensive and therefore uncommercial. For instance, a brick containing an extremely large percentage of sillimanite appears to resist the action of salt almost as well as a silica brick, but the manufacturer who set out to produce an all-sillimanite brick would be up against troubles just as great as the one who set out to produce an all-tridymite brick.

To sum up, then, this question of the relative merits of fireclay and silica bricks for coke-ovens, it seems to me that even the producer of coke from non-salty coals will be well-advised to consider seriously the use of silica bricks wherever new batteries, or repairs even, are in contemplation. Mr. Middleton has shown quite distinctly that the life of silica bricks where non-salty coals are used is a very long one, and personally I am quite convinced that sooner or later we shall have to come to the adoption of silica bricks in our own country, that the conservative element against their use will gradually but surely be borne down, and that we shall find that with non-salty coals a life at least as great as with firebrick will be obtained, whilst in those cases where highly salty coals have to be dealt with, we are confronted by factors which tell still further in favour of the use of silica brick. Silica bricks at fairly high temperatures are of greater mechanical strength than fireclay bricks, which is an important factor in connection with coke-oven practice, and one that is bound to tell in its effect upon the durability of the oven wall at high coking temperatures.

I hope to have an opportunity later on of going further into the question of the chemistry of the attack of salt and other impurities present in coals upon the various possible types of brick available for use in coke-ovens, but at the moment I cannot speak further on that particular point. I would, however, in conclusion, like to emphasize the fact which Mr. Middleton strives in his paper to drive home, viz:—that in America and also in Germany they are getting a long life from silica brick ovens, and I think we can quite anticipate that wherever silica bricks are adopted in this country also, we shall get an equally long life, no matter whether the coal which is being coked is salty or non-salty.

Mr. H. J. C. JOHNSTON:—It would not be difficult to reply in very considerable detail to the arguments which Mr. Middleton has used to support his contentions, but I will only make one or

two remarks. In the first place, Mr. Middleton, in reviewing his own forces, has underrated the strength of his enemy. He gives instances with regard to American practice where the coking temperatures are well within reach of the best classes of refractories which are at the present time being used for coke ovens in this country, and, therefore, his arguments for the use of silica appear to be rather meagre from that aspect. Again, he quotes terms of life for coke-ovens, where salty coal is used, very much below what are obtained in various districts of our own country where very salty coal is used. A difficulty which appears to arise in this matter is that there is no definite standard of firebricks or quartzite bricks or silica bricks in the three countries with which Mr. Middleton deals. If he is going to take the worst class of firebrick in a country, and compare it with the best class of silica brick in that country, or elsewhere, I am afraid that nothing very definite will result. I would suggest that something much more technical and much more in detail is required before any definite conclusion can be formed. But Mr. Middleton spoils the whole of his own argument when he attempts to discuss the changes which occur in a silica brick. If Mr. Middleton is conversant with the "TRANSACTIONS" of this Society, he will know that at the very last meeting of the Refractory Materials Section, a paper was read by Mr. H. S. Houldsworth, on behalf of himself and Prof. J. W. Cobb, in which it was stated that large quantities of silica bricks had been examined, produced by the best manufacturers in this country, and that they were practically unable to find a trace of tridymite in them. So that when Mr. Middleton says that it is a *sine qua non* that a silica brick should contain not only tridymite, but a large percentage of tridymite, it appears to be hopeless to attempt the use of British-made silica bricks for British cokeovens.

With regard to the question of salty coal, I hope Mr. Rees was not serious when he suggested that we are all satisfied with the conclusion that he has himself come to, based upon data which he feels himself unable to give us at present. Data could be produced on behalf of the manufacturers of the present types of refractories—the best grades of refractories used in coke-ovens—which would go a long way to disprove the general statement which he has put forward, and also the claims made by Mr. Middleton in his paper. Until the silica brick manufacturer can offer those wonderful tridymite bricks, which Mr. Middleton says are absolutely necessary to sustain his arguments, those who are engaged in making other classes of refractories for coke-ovens need not shut up shop.

Mr. J. W. LEE:—As a coke-oven manager, I think that we do want to get down to really practical things, and whilst it is necessary for us to understand, so far as we are able to, the changes which take place in different qualities of bricks on heating, what is more important is that we should be able to compare American

practice and British practice on something like equal grounds. Some of us have had the privilege of spending some time on the examination of American practice. We have been over to America, and have been received there in the most hospitable way by our American friends engaged in coke-oven working, as also by the brick makers of America, who have given us ample opportunity of inspecting the arrangements by which they are able to "deliver the goods" to the American coke-oven managers.

Now, speaking from a fairly long experience of carbonisation in both coking practice and gas works practice, I feel that I dare say again that, not until just now are the English brick manufacturers realising that they must really put their whole organisation in order so as to enable them to produce a silica brick which will stand up to the exigences of coking practice. I know very well that the American and English coking practices are totally different. Only in very few places in America are they coking coal that we in this country would call "wet." I might even go so far as to say in no case are they doing that. Generally speaking, it is "run of mine" coal, no compressed cakes. Only in very few cases is washed coal used, and even where washed coal is used, exceptional means are taken to reduce the moisture content of that coal to the lowest possible figure. So that rarely in American practice does one find a moisture content which will average 10 per cent. Generally speaking, the moisture is nearer 4 or 5 per cent., or whatever the natural moisture content of the coal is as delivered from the mine. Consider the difference in our country. As you know, we are very often compelled to put into our ovens a mixture of coal and water. The distinct difference must be borne in mind.

In America—I think I am right in saying—they do not, in coking practice, think in terms of salt. At present they have not found any appreciable quantity of salt in American coal. In no case were the coke-oven managers over there able to tell me what the salt content of their coal was. I believe they really thought that we were talking about things that we knew nothing at all about, when we asked them what their salt content was. Whoever heard of salt in coal ? was a suggestion that was put to me by someone over there. We have to remember always the essential differences of the two practices, and to remember also—dare I say it ?—that the silica bricks of America are made in a totally different way from either the silica or the semi-silica bricks that are supplied to us by British manufacturers.

Going back twenty years, I have very distinct recollections of some gas retorts that were built up of silica bricks—and I would here just like to agree that Mr. Middleton's terms are a trifle confusing. This setting of retorts expanded—if I remember rightly—something over eighteen inches in a length of 20 ft. And those of you who know anything at all about the appearance of

retort settings will have some idea of what they looked like after a few weeks in practice. I am not persuaded, Mr. Chairman, that there has been so very much improvement in the production of British-made silica bricks from that day to now. You can, therefore, perhaps, understand our reluctance to put them into general use.

Now I am satisfied that the British firebrick, as we at present know it, has stood up to our coking practice very well. At the same time there are conditions in English coking practice where a firebrick has failed, and one of these conditions is undoubtedly where salty coal has to be used. My conviction is that in such cases silica brick will ultimately come into use. There are places in this country where the salt content of the coal is very high indeed. Possibly these coals may never be carbonised,or certainly not until entirely different methods of dealing with them can be devised. But where there is not more than, say, 5 per cent. of salt in the coal then it is possible, I think, by the use of silica brick retorts, to carbonise these coals by the normal coking practice. At the same time, the bricks will have to be properly made, and they must be always the same. It is here where I think our English brickmakers have failed us over and over again. The bricks are too unreliable, and the variations altogether too great. For this reason I feel that a joint meeting between the Ceramic Society and the Coke-oven Managers, particularly when we can get with us our friends who have to make the bricks, is all to the good. But I repeat, in all seriousness, that the silica brick of England at the present moment is not up to the quality of the silica brick that is made for the use of coking practices in America; and part of the American coking results, exceptionally good as they are, is unquestionably due to the exceptionally good bricks that are specially made by the American brick manufacturers for the purpose. When we in England can get a silica brick that we can rely upon to be always the same, of uniform composition and expansion, I have no doubt whatever, that some of us will dare to experiment with such a brick. But at the present time (although I may be considered old-fashioned), seeing that I happen to be fortunate enough to have to deal with a coal which is not particularly salty, I am sticking fast just now to the old English firebrick, which has stood up exceptionally well to the ordinary coking practice as we at present know it in this country.

Sir Wm. Jones, K.B.E.:—It was not my intention, originally, to intervene in any way in this discussion, but in view of the aspect that it has assumed, I feel constrained to trespass just a little upon the time of the meeting. I always think that the testimony of people not directly interested in manufacturing, may perhaps possess a value even greater than the testimony of the manufacturers themselves, because however desirable the manufacturers may be of putting their case forward without any

pretence of self-interest, that self-interest is always apt to lurk in one's nature. Therefore, as a user of refractories rather than as a manufacturer of them, I might perhaps be permitted to reply to the remarks of the last speaker. We had a very unfortunate experience for a long period of years in regard to the use of silica bricks. It may be that it arose from the fact that my own firm tried to be not quite so conservative as Mr. Lee admits himself to be. We tried to be more progressive, and it cost us something. I know that when we first attempted to make use of silica bricks in retort construction the results, financial and otherwise, were extremely disappointing; in fact, I would not like to tell you of the mental worries, apart from the financial worries, which were entailed by those efforts on our part to get ahead. But I am bound to say that that unfortunate experience is now a thing of the past, and that now, in regard to retort construction, we feel justified in each successive undertaking that we engage upon to increase the depth of our silica construction, because of the fact that we do know that the silica brick makers of this country have made substantial progress during recent years, and that their bricks to-day are much more nearly approximating to those admittedly excellent bricks that are being produced in America and Germany. I myself had the opportunity last year of visiting various coke-oven installations in America, and one has to admit, as Mr. Lee has pointed out, that the practice over there does differ very materially from the general practice in this country. It is really difficult to deduce any true comparison by taking just one factor of American practice and comparing it with an individual factor of the practice in England. I feel at a loss to fully understand Mr. Lee's arguments against silica bricks. I also think that Mr. Rees' point about the comparison of silica bricks from the point of view of their lime content loses a good deal of its value when one remembers that in America the coke-ovens that are built are nearly all of material obtained from two or three recognised and reputable firms of silica brick makers, whose practice is regular and uniform. Mr. Middleton's comparison in that regard, I think, may be taken as fair, and we may assume that the lime content of the bricks is practically the same throughout.

I do not think that any exceptional importance need be placed upon Mr. Middleton's figures, or any deduction made from them, as being conclusive as to the relative values of silica or other types of bricks. I think that the tables should be taken rather as indicating the trend of thought which induced Mr. Middleton ultimately to adopt silica for his new ovens at Consett. The whole thing seems to me, from a commercial point of view, to boil down to this: what are the objections to silica bricks and what the advantages ? Do the latter outweigh the former ? I think that in days gone by the objections did outweigh the advantages because the silica bricks produced in this country were not anything

like comparable to the high quality bricks that were used in American practice. But I do say that to-day the silica brick makers in this country—somewhat tardily perhaps—are realising the important and exacting conditions with which they must needs comply, and that when you take the expansions, the risks of disruption, the higher cost, and the danger of using under-burned silica bricks, and weigh against these the advantages to be obtained in better resistivity to the action of salty coal, the ability to work at higher carbonising temperatures, and the greater abrasive resistance of silica, we may say that to-day, for coke-oven construction—and certainly it is our experience in regard to retort construction needing even higher temperatures—the trend of practice is always inclined in favour of silica bricks, and that silica bricks are beginning to assert themselves and can now be employed to advantage.

Mr. G. W. J. Bradley:—In contributing to the discussion, I can only speak as a user of coke-oven refractories without any expert knowledge of their manufacture. When one hears a paper such as this, one's hopes run high. The appeal of greater output, thermal efficiency and durability is very powerful.

In regard to thermal efficiency, the figures in table 2, where it is shown that as little as 40 per cent. of the gas may be used as fuel, are interesting. I doubt whether the majority of English coke-oven people could honestly quote a figure much less than 60 per cent. used as fuel. This is largely a question of one's method of control, and I firmly believe that we could attain thermal efficiencies not much less than those quoted by Mr. Middleton.

On the question of salty coal, I am not able to say very much, but it occurs to me that where silica walls have been used with such coals, only a temperature of about 1,100°C. has been used. It would be interesting to know what would happen if the temperature were raised to 1,300°C.

With regard to the question of conductivity, I cannot believe for a moment that the tremendous increase in the rate of carbonisation mentioned can be attributed to any great extent to the higher conductivity of silica bricks. There are other factors coming in here. I would suggest that one of these is the improved heat transfer at higher temperatures from the flame to the brick, and from the brick to the charge by radiation. Remembering Stefan's law, this factor will be appreciated. If we could have a semi-silica brick guaranteed to stand up to a working temperature of 1,300°C. and narrower ovens, the carbonising period would not fall far short of those quoted.

In connection with durability, I notice that in a paper read recently before the Society of Chemical Industry, by Wallin, it was mentioned that he had dealt with coal containing 11 per cent. of moisture quite satisfactorily in a silica oven, but remarks that changes of schedule had proved far more serious. He stated that on this account it was necessary to keep a man patching up constantly.

If changes of schedule are so serious, it would be very necessary to know what is going to happen if a silica battery has to be shut down for a period. I may be pardoned for making a point of this, for it has been my misfortune to have to shut down a coke oven plant completely something like 15 times in 6½ years through labour troubles. These stoppages ranged from several days to months. The ovens concerned are built of German semi-silica bricks, and although we have been shut down so often, I do not think the leakages have been greater than I have observed in many other ovens operating normally. This is surely a strong point in favour of semi-silica bricks. In the same connection I had about a fortnight ago some very old Stourbridge bricks taken from old non-recovery ovens. These were rectangular Coppée ovens, built in the early '70's, yet, when the bricks were taken out, they still bore the name of the maker in Stourbridge, in spite of having seen some 40 years of service. We could not wish for much better duty than this from any firebrick.

The thing we have most to complain of from English brick makers is the cement they supply for setting the bricks. One of our greatest troubles is due to leakages between the coking chamber and the flues, and much of this is traceable to the cement. We are not always sure what result we are going to get. At times the cement shrinks and is all honeycombed, thus allowing the passage of gas from oven to flue.

Taking all things together and considering the pre-war German semi-silica brick as a standard of quality, shape, and accurate size, I think we need not worry about the introduction of silica bricks, excepting in so far as they are indicated by salty coals, until more is understood about their manufacture.

Mr. E. M. Myers:—In the case of an industrial concern such as the one with which I happen to be connected, what is expected of the coke producer is that he should produce a coke which the blast furnace operator will accept as the best article for his use, firstly, from the point of view of economy, and secondly, from the point of view of the material that is ultimately to be put on the market, viz.:—pig iron. Now, for this purpose we have to apply heat treatment to coal, and, as in the ordinary course of events "beggars cannot be choosers," we have to use the coals or the fuels which are geographically situated nearest to our own particular works. It is not, therefore, an easy matter to make a definite statement that a particular refractory material will suit any particular operation, such as the heat treatment of a particular coal. That is a general expression, which may be analysed in several ways. In America, which country has very often been mentioned in this morning's discussion, the blast furnace operators have been very careful to indulge in research with respect to the kind of coke which is required to produce the best results in their blast furnaces, and they have found time and time again that one of the chief

factors in producing the best kind of coke is that the heat treatment shall be applied to their coal in a particular way. We have heard this morning of the operation of compressing or stamping coal in ovens in order to produce coke. In America, compressing of coal is regarded only as an alleviation of a difficulty, and not a cure for bad coke, and such practice would not now be tolerated. Rather than proceed with that operation, they have gone to the trouble to find out just the best heat treatment for their coal. They have definitely proved that by varying this heat treatment, they are able to produce the desired effect in the resultant coke. It follows, therefore, that in coking practice, one needs to have a refractory material that will stand up to what is required of it.

Now in order to arrive at the best coke which a coke-oven can produce with the kind of coal that is available, the heat treatment necessary must be very carefully studied, and I am convinced that by increasing the speed of carbonisation, all the disadvantages of compression and the other things which are bound up with it, can be dispensed with entirely, and that the blast furnace operator can be assured at the same time of a very much better product than that with which it was possible to provide him by the old methods of working. The factor that is going to bring this about is, to my mind, silica bricks and rapid coking. One is quite aware, however, of the difficulties which are likely to beset the path of most coke-oven or carbonisation engineers in the use of silica material. As we have heard, and it is a fact which I can confirm from observations, the Americans have overcome all their difficulties and nothing but silica bricks are used in the construction of their ovens.

The great thing, in my opinion—and here I am quite in agreement with Mr. Bradley—in the use of silica bricks for carbonising, either in retorts or in coke-ovens, is that the retort or the coke-oven should be kept at as near a constant temperature as is possible to produce the best results. I admit that there is a greater danger with silica bricks if there is anything like a wide variation between the maximum and minimum temperatures at which the plant is worked, than there is when using ordinary fireclay or semi-silica.

Unfortunately, Mr. Bradley comes from a part of the country where labour troubles are rather rife, and where one has to manipulate one's particular plant to allow for these local conditions. In America, on the other hand, one often finds that even where labour troubles do exist, the fortunate arrangement of the plant enables either the coke-oven or the steel workers to be able to have a supply of natural gas which they can switch on to their plant and thus keep the carbonising chambers warm during the period when they are shut down. In this way they are not troubled to the same extent as we are in this country with the variations of temperature.

But what I do feel about it is this: if due care is taken in

the manipulation of coke-ovens in the heating up of the battery or the setting of the retorts, and if the greatest care is used in the earlier stages of their life, then the advantages which are to be derived from silica material far outweigh the disadvantages, and a better balance sheet can be shown than in the case of working with fireclay. What we want to be able to tell the refractory materials manufacturer is this: we require bricks that are true in shape; which will allow the bricklayer to lay them with the minimum quantity of cement or jointing material, and which, when placed in the carbonising chambers, will be of such a composition that the amount of leakage shall be reduced to the lowest possible minimum. What we require to obtain is the greatest amount of surplus gas and the greatest amount of by-products, and at the same time produce the best kind of coke and the greatest possible amount of it.

Lt.-Col. C. W. Thomas:—It has been an extremely interesting discussion, certainly from the point of view of the manufacturer of silica material, semi-silica or even of a common firebrick. I do not know whether the speaker who referred to the question of jointing material did not touch upon one of the critical spots. It has always been a belief of mine that whatever form of furnace construction you may be considering, jointing material is a most important factor in the life of the furnace, and I can conceive of no more critical conditions for a jointing material than in the working of a coke-oven. This is a point to which, I think, attention might well be directed. I do not know whether Mr. Johnston will take comfort from what was said by one speaker about 40 years life of a fireclay brick, or whether he will feel the reverse sensation, since it happened to come from this particular district. But, if I may suggest a pointer for the future activities of the Section, this morning's discussion has been valuable in many ways; it has not only dealt with the particular set of circumstances or set of difficulties which occurs in connection with coke-ovens, but I think it has shown very markedly the advantages to be got from a mutual discussion of matters of this sort with the people who have to use our materials. I would suggest to the Section that this should be borne in mind, and that in the future, we should endeavour to arrange similar mutual discussions on various points affecting other industries in connection with which refractory materials are used. The whole question has been very thoroughly gone into, the points that have been raised have been extremely interesting and valuable, and I consider it very important that all those who are in the position of being manufacturers of refractory materials of various types should give their most careful consideration to the difficulties which have been brought up by the users of their commodities.

Mr. G. M. Gill:—As a visitor to this meeting, I am very glad

to have an opportunity of saying a few words on the subject before us. My experience has been gained entirely in gas works, and the subject of the paper is therefore a very interesting one to me, as it must be to gas engineers in general. Like some of the others present in the room, I paid a visit to America some two years ago. I went at the request of my company—the South Metropolitan Gas Co., of which I was the chief engineer until a short time ago—and I not only visited a large number of gas works, but also inspected a considerable number of coke ovens, because I wanted to see the results of the use of silica material in practice. I noticed that silica was being used universally in America, not only in connection with coke-oven plants, but also in gas works. I was very much impressed with the great increase in the output of gas or coke as the result of using this material. I came to the conclusion that the Americans were obtaining from 25 to 100 per cent. more duty out of their plants than we were obtaining in this country, and I attributed that chiefly to the higher temperatures which are everywhere found in America, not only in coke-oven plants, but also in gas works, and also to the higher conductivity of the silica material. At one works that I visited, a gas engineer took pains to demonstrate this to me, and I came to the conclusion that there was really a definite increase of conductivity with the silica material, leading to an increased output. I made certain notes at the time to the effect that 15 per cent. of extra gas was obtained as the result of higher conductivity alone of the silica material, and only this year, at the meeting of the Institute of Gas Engineers, the President, Mr. Hardie, presented some figures dealing with the temperatures of the outside and inside of silica retorts, which revealed the fact that the difference between the outside and inside temperatures was considerably less with silica than was the case with the fireclay retorts.

Now if you can get quite a small increase in temperature this gives you a big increase in the output of gas. In my own experience I found that an increase in temperature of only 8 per cent. inside the combustion chamber gave an increased output of gas of something like 26 per cent., so that if you can only get a material which will enable you to use a higher temperature you will, without doubt, be able to get a very much increased output. Up to the present, I have been content to use a material which can be termed neither "silica" nor "fireclay," but containing well over 80 per cent. of silica, which I have used both for the retorts and for the material around the retorts. I look upon this at the moment as the happy medium between fireclay and silica. You have not the risk of using the higher percentage of silica material, with its expansive properties, although you have advantages that you do not get with fireclay. In America, when using silica, they have to take very special precautions to provide against the large expansion of the material, and I noticed that the retorts were

built up in blocks with millboard placed between the joints, varying from $\frac{1}{16}$ in. to $\frac{3}{32}$ in. in thickness. This seemed to me to be a retrograde movement as compared with using moulded retorts. The expense also was greater, but there is no doubt that they were getting enormously increased output as compared with the achievements of the gas engineers of this country. Of course, what is wanted is a high percentage silica material without the great expansion with which we associate it at the present time. That is the conclusion I have come to. I do not know whether it is possible to make a material with a lower expansion, but that is what is wanted.

Mr. T. Biddulph-Smith (communicated):—I would like to take the opportunity of congratulating Mr. Middleton on his paper, and at the same time, to make a few remarks that occurred to me. (1) With regard to the comparative thermal conductivity between silica and quartzite, I venture to suggest that this factor does not enter in any way into the physical process of coal carbonisation. The rate of conductivity when passing from the conducting wall to the charge of coal or coke, both of which latter materials are poorer thermal conductors than either silica or quartzite, will depend upon the rate at which the heat can be conveyed by the coke layer, next to the wall, into the interior parts of the oven. Consequently, at any fixed temperature, the rate of conductivity of heat from a flue to a charge of coal by any refractory material, will be a constant, and, therefore, the rate of carbonisation will vary inversely with the temperature. Hence, in comparing the two materials as regards output, the main point to watch is the limit of temperature which can be safely applied ; (2) in order to be strictly fair in the comparison between the outputs of plants built of the two materials, I would point out that from table 2 of Mr. Middleton's paper, the coal "A" contains 34·75 per cent. of volatile hydrocarbons, and yet 74·00 per cent. of coke is obtained. Also the coal "C" contains 31·00 per cent. of volatile hydrocarbons and 75·00 per cent. of coke is obtained. Evidently these cokes contain 8 per cent. and 6 per cent. of volatile matter respectively, and confirm the remarks which I recently made in my paper before the Midland Section, that:—"The practice in that country (America) in most cases, is to draw the ovens to time table, whether they are completely burned off or not." I venture to remark that the British producer could not hope to supply coke to our blast furnaces with such a high volatile hydrocarbon content; (3) given a good silica brick, its use where poor caking coke is carbonised would be a great advantage, both with regard to output and quality. This also applies where salty coals are used, but in the latter case the carbonisation temperature should vary inversely with the coking index, the silica being chosen on account of its greater resistance to salt-corrosion, rather than on account of any increase of thermal conductivity.

MR. MIDDLETON:—I am pleased to find that the subject dealt with in my paper has provided such a very interesting topic for discussion, and that we have been fortunate enough to hear the views of gentlemen closely associated with the Gas Industry, in the persons of Sir Wm. Jones and Mr. G. M. Gill, and to find contributions to the discussion from such well known brickmakers as Mr. Johnston and Lieut. Col. Thomas, as well as from members of the Technical Staffs of the Universities so ably represented by Mr. Rees, in addition to Managers of Coke Works, for whom this paper was originally prepared.

The feature of the discussion which strikes me most is the want of faith in the ability of the silica brick maker to turn out a satisfactory article, rather than any attempt to challenge seriously the advantages that I have claimed for ovens built of silica.

There is no doubt that the material turned out from silica brickworks in the past left a great deal to be desired, and that manufacturers understood little of the nature of the material with which they were working. It was because I shared these doubts, and was not satisfied that any of the silica brick makers in the country could make a brick approaching those made by the American brickmakers, that I recommended my firm to extend our brickworks and make the bricks for our new coke plant at Consett, the ovens of which are being built of silica bricks of our own manufacture.

In the short time since this decision on our part was taken, there has no doubt been a greater appreciation, on the part of the silica brick makers, of the necessarily exacting requirements of coke oven and gas engineers, and there has been some improvement in the methods of manufacture and the quality of the goods turned out, as has already been testified by Sir Wm. Jones.

Before starting to build our new brickworks I had, on two occasions, spent several weeks in American silica brickworks, and I have paid a further visit to them since we started manufacturing ourselves. I wish to take this opportunity of publicly acknowledging the very great help which I received from the American silica brick makers.

It would be impossible to overstate the indebtedness that I feel to the Managers and Technical Staff of the Harbison Walker Refractories Company and The American Refractories Company, for the whole-hearted help which they gave me. No trouble seemed too great for them in their effort to give me all the information I required in designing our new works and in learning their method of manufacture, with the result that we are to-day able to turn out a brick which will stand comparison in every way with the excellent products which they set us an example in making.

We are now, in spite of the doubts expressed by Mr. Johnston, daily producing material containing the desired amount of tridymite, so that Mr. Johnston and those for whom he is speaking can, to use his own metaphor, "put up their shutters" at once if they are

relying on the inability of the silica brick makers to do this in order "to keep their shops open."

To deal fully with the many interesting points raised in the valuable discussion we have had would require a paper as long as the one already read. I will only attempt, therefore, to deal briefly with the arguments of those who have directly criticised any of the arguments that I have brought forward.

I think Mr. Smith is entirely wrong when he suggests that the comparative thermal conductivity of the material of which the walls are built is not one of the factors affecting the period of carbonisation. Heat has, of course, during the process of carbonisation, to be transferred through the coal and coke as he states, but it has also to be conveyed through the body of the oven wall, from the combustion chamber to the contents of the coking chamber, and whilst the conductivity of the coal and coke is a constant for any particular class of coal, the conductivity of the wall is a variable if different materials are used, and any improvement in the conductivity of the material of which the walls are built will result in a reduction of the period of carbonisation.

For example, when an oven is newly charged with coal, you have all observed that the temperature of the walls on the inside of the oven immediately falls, due to the fact that heat is being taken away from it by coal in contact with it, more rapidly than it is supplied by the combustion of the gas inside the combustion chamber. I think that this drop in temperature on the walls of the coking chamber will be less and that it will be more quickly recovered in the case of walls built with a material of relatively high conductivity.

Mr. Smith is also incorrect in the conclusion which he draws in the latter part of his discussion. The coke referred to does not contain 8 per cent. and 6 per cent. of volatile matter respectively. The difference that he refers to in my figures is due to the well known fact that the volatile matter in the coal, as determined in the laboratory, is greater than that obtained in practice, due to the fact that hydrocarbons, which are not decomposed in the laboratory test, are decomposed in practice and the carbon from this decomposition goes to increase the amount of coke made.

I agree with Mr. Rees' criticism that the term "quartzite" is not a happy one. I used it because it was the term used in America and Germany when comparing the two classes of material that we have been discussing. I would have used the term "half ganister" instead of "quartzite" if it were not for the fact that the term "ganister brick" is already applied to the brick, made with about $\frac{5}{8}$ of ganister and $\frac{3}{8}$ of fireclay, by many manufacturers and users. I daresay the term "semi-silica," as suggested by Mr. Rees, is as good as any.

I am not putting forward the method of evaluating the extent of the conversion of the quartz in a silica brick, by means of the

specific gravity, as one of the highest scientific accuracy, but only as a rough but ready works test. I have used it a great deal during the last two years and am convinced that it is of great value.

Mr. Johnston's characteristic attempt to defend the material hitherto used for coke oven building against the attack made upon its position is not very convincing.

He states that I give instances with regard to American practice where the coking temperatures are well within reach of the best class of refractories which are at present being used. The only reference in my paper which will, I think, bear this interpretation is on page 173, and the low temperature there used was only due to the fact that the works were short of coal at the time, and the period of carbonising had to be increased and the temperature decreased in consequence. No manufacturer of the fireclay classes of material now being used would suggest for a moment that his goods could stand up to the temperatures used in American coking practice and which, I suggest, it is advantageous to be able to use in this country.

There is nothing in my paper to suggest that any comparison has been made between the worst class of firebricks in one country, and the best class of silica bricks in another.

Because I say that it is desirable to have as much as possible of the silica in a coke oven brick in the form of tridymite, and because "Professor Cobb and Mr. Houldsworth have examined large quantities of silica bricks made by the best manufacturers in this country and were practically unable to find a trace of tridymite in them," Mr. Johnston says that I spoil the whole of my argument. I am afraid I must cruelly deprive him of the false feeling of security that the statement of these gentlemen was giving him, as we are daily producing coke oven bricks at our Consett brickworks, the quartz of which is entirely converted and with a tridymite content up to 30 per cent.

We have examined a number of coke oven bricks by the best American Manufacturers, and find the same result.

I quite agree that it is highly probable Professor Cobb and Mr. Houldsworth might examine a very large number of silica bricks as turned out by manufacturers in this country without finding any tridymite. A very large number of them are composed entirely of unconverted quartz, but such bricks are unsuitable for the building of walls of coke ovens or gas retorts; they have not been properly treated for such a service, and were, very probably, never intended for it.

I have examined a number of them myself. I have also carried my examination a stage further, and reburnt such bricks at the temperature at which coke oven and gas works material should be burnt, and found after the reburning that the unconverted quartz had disappeared, and its place taken by cristobalite and tridymite, as should be the case in the service we are considering.

It is a comparatively expensive rather than a difficult matter

to obtain these results, provided that manufacturers have suitable kilns in which to burn the goods. I believe a majority of the kilns in this country are quite unsuitable for burning this class of goods.

We bought a small silica brickworks before building our own; it contained the usual type of kiln used in this country and we burned the lot of them down in a few weeks by working them at the temperatures necessary to burn coke works and gas works material.

It is quite possible to make slica bricks of perfect shape and composition, if the right methods are adopted. The fact that much unsuitable material is made is the fault of the brick maker and not of the material.

The only other point raised in the discussion to which I propose to refer, is that made by Mr. Bradley, with regard to the probable effect on silica walls of constant shutting down due to labour disputes or other causes.

In the old days, we used to think that a coke oven could not be shut down without very serious damage to the walls. We have found by practice, that if it is carefully done, the damage is very small, and I quite expect experience will prove that the same is the case with walls built of silica bricks.

I am basing this statement on the fact that I have, under my charge, brick kilns, the walls of which are built of silica and these, in normal course of brickmaking, have to be shut down and heated up again much more often than could possibly be the case with coke ovens under any conceivable conditions. The walls in question, which have been heated up and cooled down, in some cases 20 times, and in others 50 times, are no more cracked than similar walls built of fireclay and semi-silica bricks. They still look good for many years' service.

XIII.—An Examination of Refractories by the Oxygen Blow Pipe.

By Algernon Lewin Curtis.

IT is sometimes necessary to examine quickly the refractory qualities of raw materials submitted as such, and to compare different materials one with another during examination.

In the ordinary method of test a prospective refractory undergoes ultimate chemical analysis, and if then considered satisfactory, pyramids or truncated cones of the material finely ground are made up and exposed to varying temperatures in different types of furnaces.

The result of such tests gives a percentage of total fluxes, and a number of distorted test pieces, which have undergone more or less change, according to the temperatures at which they were exposed.

Although the above combination of test is an efficient one, the time and expense necessary to carry it out render large numbers of such tests a big undertaking.

In order to save time when examining small amounts of refractory material, a method was adopted for bringing into use the Oxygen-Coal-Gas-Blowpipe. This meant exposing the test piece to a strong fixed blowpipe flame and using portable test pieces of a briquette nature. As it was found desirable to standardise the form of test piece employed, a rectangular fireclay trough was used. Refractories for examination were ground and sieved through 100 or 200 mesh sieves, mixed with water or dextrin, and then pressed into the trough with a palate knife and dried at 110°C. for one hour. In the case of fireclays a higher temperature is suggested.

In order to move the fireclay trough containing material for examination in a horizontal plane under the blowpipe flame, an ordinary lathe bed was used, on the surface of which a firebrick was mounted. The flame of the blowpipe was kept under control by securing the blowpipe itself in a suitable stand provided with fittings capable of adjustment, and the oxygen pressure was regulated by an automatic regulator or cylinder.

In order to provide a flame with a specific temperature, check test pieces were prepared from Seger Cones by crushing the latter, making them into a paste and enclosing the material in a fireclay trough, finally drying at a fairly high temperature. Assuming that Seger Cone No. 18 would be used for check test pieces representing a temperature of approximately 1,500°C. then the blowpipe flame would be regulated so as to just fuse the cone and test piece travelled along under the blowpipe flame, the time taken being noted in seconds. Having determined the approximate

temperature of the flame, test pieces of similar height containing different materials followed on under the flame.

At first it was found somewhat difficult to detect, either with the naked eye or glasses, the exact point and time at which the material began to fuse; securing the exact adjustment of flame was also tedious. To overcome this difficulty, numerous experiments were made with varying kinds of apparatus to see if some means could be found of magnifying what took place when a refractory was exposed to a high-temperature blowpipe flame.

As a camera was deemed necessary, a crude wooden stand was improvised to carry the camera and span the lathe bed holding the test piece. The idea was to mount in a microscopic table, in place of an Abbe condenser, a tube carrying a short focus telescopic objective of high order. A series of graduated diaphragms was provided in this tube. The function of the telescopic objective and diaphragms was to project an air image of part of the illumined test piece to the plane of the stage of a microscope. Instead of using a body tube in the microscope, a wooden front carrying a metal fitting was substituted, the wooden front forming part of the camera and the metal fitting for a microscopic objective. By inserting the microscopic objective in the metal fitting this objective became a photographic objective, and the air image projected by the telescopic objective became magnified by it, focussing being carried out with the ordinary rack mechanism of the microscope.

The camera was designed to give suitable extensions and consequently increased magnification. In applying optical apparatus to a highly heated body, it was found necessary to work as close as possible to the object under examination. As safety of the telescopic objective was of paramount importance, 7-10 inches was considered the shortest distance that could be safely used. A number of experiments were carried out for the purpose of providing a suitable lens protector to enable this working distance to be shortened, but all proved futile.

By arranging the blowpipe flame at an obtuse angle to the test piece, it was found that work could be carried on for a few minutes without any danger to the lens, even when working at 7 inches from the test piece at a high temperature. When using the apparatus, it was found that, with a minimum flame temperature of 1,500°C. a working magnification of from 15-35 diameters could be obtained with an ordinary $\frac{1}{2}$-inch microscopic objective. Photographs of incandescent bodies could be taken with exposures varying from 5 to 60 seconds at flame temperatures of 1,450°C. to 1,750°C. To test the usefulness of the apparatus, 7 test pieces were made up from Seger cones 6a-10-14-18-27-32-36. A number of cones from each series were ground in a Wedgwood mortar and sieved through a 100 mesh sieve. The material was then moistened with water, pressed into fireclay troughs $1\frac{3}{16} \times \frac{7}{8} \times \frac{1}{4}$, the recess being approximately $\frac{1}{8}$ deep. The surfaces of all troughs were previously ground level and

were of the same height. After having been smoothed off with a trowel, the moistened material was dried at 110°C.

Seven test pieces of each of the following were then similarly prepared, viz. :—two different sets of Bauxite Clay—one set of a mixture of the two previous samples, four sets of Scotch Fireclays, comprising seven sets in all plus one set of Seger Cone check test pieces.

The test pieces were designated thus :—

Seger Cone	= S.C. and number.
1st Bauxitic Clay Sample	= A.
2nd ,, ,, ,,	= B.
Mixed ,, ,, ,,	= C.
1st Scotch Fireclay ,,	= D.
2nd ,, ,, ,,	= E.
3rd ,, ,, ,,	= F.
4th ,, ,, ,,	= G.

The S.C.6a. test piece was first exposed to the blowpipe flame until it showed signs of fusion. This was then travelled along slowly under the flame, the remaining seven test pieces following on in the order given. Every now and again, the S.C.6a test piece was exposed as a check test. An examination of the test pieces showed the following :—

1. "F" unfortunately "blew," probably owing to its having been insufficiently dried. As its water content was 25%, insufficient care was taken in drying the test piece. This was rather a manipulative error than a fault of the apparatus.
2. The most affected test pieces were the Scotch fireclays which showed "high shrinkage," "lattice cracking" and in the case of G a distinct tendency towards heat attack.
3. The bauxitic samples showed less than half the shrinkage, practically no "lattice cracking" and, with the exception of "A," very little "blistering."

The illumination from a small blowpipe flame at 1,200° was hardly sufficient to get good definition on the screen. Similar test pieces were next exposed to a blowpipe flame approximating 1,300°. Unfortunately, three test pieces collapsed, viz. : D, F, G. This collapse was caused by insufficient drying and should have been avoided. In this test the S.C.10 test piece fused. Of the bauxitic clays, B was the least affected. E of the Scotch fireclays showed shrinkage and "laced" cracking. A showed signs of blistering.

A further set of test pieces was then exposed to a blowpipe flame temperature sufficient to just melt cone 14, giving an approximate temperature of 1,410°. One glance at the test pieces exposed will show that G of the Scotch fireclay series finds no place in the zone of refractory clays, while test pieces D, E and F all have a high shrinkage. Of the three bauxitic clays two samples, B and C indicate results worthy of further investigation.

D of the Scotch fireclays commenced "pitting," and E and F latticed cracked. Of the bauxitic clays, A developed "linear" cracking and blistering. C blistered and B was the least affected, due probably to a minimum titanium oxide content. Thus far in the tests it will be seen that the Scotch fireclay G cannot be included in the category of high-grade refractory fireclays, owing to its high (assumed) iron-content—and D, E, F, though not greatly affected by heat, all possess a high shrinkage.

The bauxitic clays show results worthy of very close examination. It was expected that the action of a flame temperature sufficient to melt Seger Cone 18, approximately 1,500°, would produce interesting results. Unfortunately, F test piece blew during exposure to this approximate temperature. This test piece with its high water content should have been dried at a higher temperature, and for a longer period than the others.

S.C.18 test piece showed obvious signs of fusion.

The Scotch fireclay G proved beyond all doubt its inability to withstand even 1,500° approximately. D showed, in addition to shrinkage, signs of heat attack, while of the Scotch fireclays, E was the least affected by heat. The bauxitic clays A and C commenced to "blister" which might be attributed to high titanium oxide, C possibly borrowing this from test sample A. The test piece B being probably lower in titanium oxide was least affected of all. A summary of this test would seem to suggest that B and E materials were good refractories at this temperature. A further batch of test pieces was exposed to a flame temperature sufficiently strong to just melt Seger Cone 27, approximately 1,610° made up in the usual test piece form. An examination of the S.C. 27 test piece shows that this was accomplished. Test piece A of the bauxitic clays was apparently insufficiently dried out, as "waving" action took place, indicating a film of moisture under the skin of the test piece face. Had it remained firm, in all probability it would have blistered. All the Scotch fireclays showed excessive shrinkage, F most of all. E apparently was the least affected by heat and G the most affected of the Scotch group.

B of the bauxitic clays stood out alone, being scarcely affected by the heat at all, and with the exception of low shrinkage suggested a good material. It was now thought desirable to submit test pieces to a flame temperature capable of fusing a test piece composed of Seger Cone 32, approximating a temperature of 1710°. The S.C. 32 test piece was easily fused and in the following, the condition of other test pieces is described.

B of the bauxitic clay group was the least affected by heat of any of the seven test pieces, and as far as the evidence goes, suggests an extremely useful refractory, possessing ability to withstand high temperatures. C, which was a mixture of 50% A and 50% B, again showed blistering. As blistering was practic-

ally absent in B, it might be assumed that, since A was high in titanium oxide, the 50% of A mixed with B, was the cause of blistering in C. Of the Scotch fireclays, G can be ruled out as useless, while D, E and F all gave high shrinkage. F exhibited considerable "lattice" cracking, whilst D and E showed signs of heat attack. Before concluding the experiment, it was decided to see what effect a temperature capable of fusing a test piece composed of cones 36, approximating 1,790°, had on the remaining 7 test pieces. A flame temperature was, therefore, set, and all the test pieces exposed, with the following results :—

Possibly, in the author's eagerness to complete the test, prolonged drying of test pieces was overlooked, as the S.C. 36 test piece blew and cracked. This did not, however, prevent the test piece from being exposed to the full blast of the flame. The results of this test could be summarised as follows :—

"S.C.36" fused, and cracked through blowing.

Bauxitic Clays.

"A." Waving action took place through moisture, fusion on edges.

"B." Blistering occurred—cracking through moisture and evidence of heat attack.

"C." Blistering, cracking, fusion on edges.

Scotch Fireclays.

"D." Surface fusion, high shrinkage.

"E." Surface fusion to black slag, depicting fairly high iron content, high shrinkage.

"F." Surface fusion, least affected, very high shrinkage.

"G." Surface fusion, most affected, very high iron content.

It might be assumed from the above, that the bauxitic clay B would have stood firm had the test piece been more thoroughly dried. Had the face of the test piece remained firm, it would probably have been least affected by heat. Samples A and B certainly showed signs of fusion, but less so than test pieces D, E and F. Of the Scotch fireclays, F seems the least affected by heat attack, but shows very high shrinkage.

In making a survey of the whole tests, representing 56 test pieces from 7 different materials, plus 7 test pieces of Seger cones, it may be seen, that "surface attack" from heat, and shrinkage, can be readily studied ; and those materials first affected by heat are inferior to materials which resist attack to the last. In this case, it would seem that the best bauxitic clay tested was less liable to heat attack than the Scotch fireclays, besides possessing less shrinkage. On the other hand, a distinct difference in quality of such bauxitic blays can be assumed from the difference shown in the heat attack of the three test pieces. Of the four Scotch fireclays, it is easily seen that the test piece marked G has little claim to a place as a refractory fireclay. The Fireclays D, E and F

however, can all claim to belong to the refractory fireclay group, their chief detriment being high shrinkage.

It is expected that the methods outlined in the above paper will be very openly criticised, especially the question of "temperature determination," in view of the fact that no pyrometric instruments were employed. In this connection, it might be stated that a very great deal of attention and experiment has been given to the question of finding a suitable optical, or other pyrometer for checking the temperatures used. For some time a "Fery" absorption pyrometer was used with success, when a Cathetometer was employed to check the flame of lamp. This instrument, however, was understood by experienced workers to read high, and the oval patch was abandoned for the disappearing filament. Many other forms of instrument were tried, the nearest approach to accuracy being obtained with Messrs. Tinsleys new type of pyrometer. Unfortunately, the platinum wire filament in the latter instrument is insufficiently large to give good matching or disappearing results on the small size of test piece used, but with a large body its accuracy and results are excellent.

The author is engaged at the present time in trying to perfect a suitable optical instrument to balance any difference which occurs in flame temperatures when fusing Seger cone test pieces, and it is hoped this will be ready to use with the improved blowpipe apparatus now being constructed.

In conclusion, it is hoped that the rough idea outlined in the above pages will only be treated as an idea, not as a claim for the most efficient method of testing refractories. Great accuracy is not claimed for flame temperature as compared with the accuracy possible in an electric or surface combustion furnace. Sufficient accuracy however, and permanence of flame is possible with an experienced worker to enable test pieces to be compared, giving a relative value to the test. When it is considered that 56 test pieces can be dealt with, after suitable preparation, by an experienced worker in one day, the speed and ease of working of such a method will commend itself to the busy man, hitherto accustomed to wait days for results of ultimate chemical analyses and cone tests.

XIV.—Technical Education in Relation to the Refractories Industry.

By G. W. Hefford.

IT is not impossible that the lack of enthusiasm for, and in some quarters the definite suspicion of technical education, which industry in general, and the Refractories Industry in particular manifests, is due to a too narrow concept of what technical education really means and what its functions are, and at the outset it may be useful to attempt to get a clear view of the problem under consideration.

If we look backward over the story of the development of the human race we shall note a fairly clear relation between that progress and the increased and more efficient use of natural products. Two instances so widely apart as the cereals and the ores of the metals quickly come into mind and the widest used natural substance of your industry—clay—affords an instance over which we may halt for a moment. Before the early specimens of the human race knew anything of fire, the use of clay, sunburnt clay, began, and through the ages as experience has grown the use of burnt clay has increased, and as the use has increased the demands of users have increased, developments in other industries have suggested further uses for clay, these further possibilities have led to increased severity in the demands of would-be users, and these demands have to be met and can only be met by a more accurate and detailed knowledge of the raw material.

Experience has taught, but the knowledge has been largely empiric, difficult to pass on effectively, difficult to record, hence progress has been slow. Ask yourselves two or three fundamental questons about clay and see whether you are satisfied that you can give full and exact answers.

There comes a time in the use of raw materials when empiricism is no longer sufficient: it matters not whether the raw material is cotton or clay, exact knowledge becomes essential, and to determine that exact knowledge, highly trained investigators are required; the stage of research is reached.

The advance in experience and knowledge made by one generation over its predecessor depends on how nearly the latter can start where the former left off, and this depends largely on the accuracy and efficiency with which past knowledge and experience can be recorded. One of the premises of an accurate record is accurate observation and if progress is to be made imagination must play its part.

Nearly 100 generations ago Thales of Miletus recorded the observation that amber when rubbed attracted light bodies; some

10 generations back Gilbert applied this observation to what we should regard to-day as a very simple form of investigation. It has required the keen investigation and imagination of this generation to shew that, in the apparently trivial observation made nearly 3,000 years ago, lay a possible key to the marvellous possibilities of atomic energy.

It requires knowledge and imagination to see any connection between the brilliant-hued, fairy light soap bubble, and the drying of a commonplace brick ; yet the connection exists and is important.

Possibly sufficient has been said to remind you that education bearing on any industry must involve a training in accurate observation, accurate reasoning and recording ; it must have relation to natural products and the processes involved in their treatment and use and it must stimulate imagination. This is a big programme and it must take time—a good deal of time.

Let us say then that technical education includes all that experience and knowledge and discipline which tend to make any worker in any capacity of greater efficiency in any particular industry. If this view is accepted, it is clear that real technical education involves something more than repetitive processes for the majority, and probably specialised mathematics, physics and chemistry for the elect.

Among other agencies the classroom and laboratory, the library and the works have their several parts to play, and those parts will vary with the personality and aims of the individual to be educated.

What part can the Technical School or the University usefully undertake ?

It is fair to say, and the statement implies no reproach, that for the majority of those in the refractories industry, higher or specialised technical instruction is unnecessary and for them the function of the educational institution will be to preserve or develop the power to read and calculate and draw ; to observe accurately, to develop reasoning and a sense of responsibility. This sounds a lot, but there is little doubt it can be accomplished through the medium of suitably simple calculations and drawing, elementary science and some descriptive work with some encouragement to read. The use of the word English has been avoided because the prejudice of the Englishman is against it—possibly on account of unfortunate experience: but it is reasonably certain that clear progressive thought is impossible unless thought can be expressed or recorded accurately. Inaccurate expression will lead to subsequent inaccurate thought, hence English in some guise is essential; and it is equally essential that the calculations and drawing and science should have a live interest given to them by clear reference to the material and processes of which the student has experience, or about which he may reasonably be supposed to possess curiosity. It would be all to the good if opportunity were found for some atten-

tion to what may be called factory or works hygiene. Simple precautions, simple remedial measures, may reduce the amount of "broken time."

It is customary to be pessimistic and despondent about the effects and utility of such attempts as have been made in technical education, but when it is remembered that a very great proportion of that education has been carried out under unsatisfactory conditions, that after a full day's work few teachers or students are in a physical or mental condition to work efficiently for another 3 hours in the evening, the wonder is not that so little, but that so much has been accomplished, not because of, but in spite of conditions. It is a testimony to the determination and grit of those who have given and those who have received instruction that so much good work has been done. Again, it is a platitude that regularity is an essential of effective training whether for the body or the mind, yet it has been far too frequently the custom to have something like a five months break in each year of training. Time is an important factor, yet the time that is available in an ordinary winter session is comparable with only two months of ordinary schooldays. It is unreasonable to suppose that any individual can work efficiently morning, noon and night all the year round; and until industry perceives that shortness of time and long breaks in training operate against efficiency of technical education, and until it really tackles the problem of making some training in the day-time possible, the effects are bound to fall short of those desired.

It is not unusual to find that a position roughly defined by the expression: "It is the worker's job to *do*, not to *think*" is taken up by certain people. This appears unfortunate. If a man is doing good work he tends to become a good and useful member—not merely of an industry but of society; if his work is generally bad or unsatisfactory, the worker tends to become a less satisfactory person. If a worker is to do good work he must be interested in it, and that means he must be able to think about it. Indeed it is along that line that progress lies: the more interested and contented the workers in an industry are the more satisfactory will the industry be.

There is a real need for educational opportunity for the mass of the workers. Of course there will be degrees of response, that is true of all forms of stimulus whether spiritual, mental or physical, but the most effective response will come from the better specimens and it is those who will help industry along.

It is fair to assume that the majority of those likely to occupy responsible positions in the industry will have had a good general education. In any case a good general education is an essential foundation for higher technical education. Upon that foundation a good training in scientific method, method of observation and thought, can be built. This training can be given in a variety of ways.

Industry quite often is prepared to be persuaded that apart from any question of training chemistry is useful because it is expected to answer the question "What is it made of?" and it is expected to answer quite quickly. The utility of a knowledge of physics is less usually allowed, yet heat is of fundamental importance in connection with many industries and certain physical properties and changes make all the difference between a satisfactory and unsatisfactory product. The mere mention of mathematics automatically applies the closure to any general discussion of this problem, yet mathematics are an essential equipment of the investigator of to-day. The great point is that the training in science should be sound and broad and not too early specialised.

The association of works experience with this academic training, whether in the Technical School or the University, (more usual in the former case than the latter) provides a thorny problem. There are those who urge, and produce apparently sound arguments in favour of close association. Others suggest that such association is not necessary until post-graduate time and they point with confidence to many outstanding instances in industries so widely different as brewing and refractories, where a highly trained scientific man with no practical experience of an industry has relatively quickly acquired sufficient knowledge to make him of very great value. There is some ground for thinking that whether a side by side academic training and works training is good or not depends largely upon the temperament and must depend on the opportunities of the individual.

There are undoubtedly numbers of first-rate men in the industry, so far as their experience goes *really* first-rate, but for lack of suitable scientific training they are unable to translate the results of research into works practice. Perhaps the suggestion may be permitted that the function of research work in connection with industry is something more than the provision of foolproof tips; it is to determine principles, and constants, which, by men with training, acumen and imagination can be applied in the circumstances of the particular works in which they are interested. This does not appear to be either the place or the time to discuss syllabuses and details of courses of instruction, but the need for a study of Factory Organisation is so great that it is worth special mention. In connection with this matter the applications of mechanical principles are of no greater importance than considerations of economic use of heat, yet opportunities for using excess heat are frequently neglected in places where ingenious mechanical devices exist.

Probably sufficient has been said about the work that may be done by the educational institution; now for certain suggestions about the parts industry may play, because co-operation is absolutely essential.

The vast majority in an industry are in it for what they can

get out of it, the minimum requirement being a livelihood. If an industry is to survive it must compete successfully with other industries, so whether we regard the industry as a whole or the workers in it as individuals the first stimulant to progress is self-preservation. In a good many cases ambition—laudable ambition—exists ; this may express itself in a desire for "bigger business" or promotion within a works, or to another works. The driving power which usually stimulates a youth or a man to study is the desire to "get on" and in this connection it seems necessary to plead for the sympathy of industry, because every real progress within an industry is for the good of that industry.

If technical education for the refractories industry is to be effective, those persons willing to devote energy and give time to study must be encouraged. It is highly desirable that time should be allowed in the daytime ; if that cannot be done it may be possible to make concessions so that attendance in the evening may be made as convenient as possible. True sympathy means a great deal to the young worker. Instances have occurred in an industry—not distantly related to yours—where students have found it necessary to attend technical classes under names different from their own in order to avoid real persecution ; the reason for that persecution is not far to seek. In other industries attempts to provide technical instruction have failed by reason of the active opposition of men in moderately responsible positions. Sympathy and encouragement are necessary.

The next point is approached with some diffidence, but it really is important.

The worker—whether his work is menial or highly technical—should feel confident that any useful suggestion he may make, whether trivial or of far reaching consequence shall be credited to him in some suitable way. This matter of confidence is of real importance, and cases have been known where Works Committees have performed a useful function in this connection.

The refractories industry appears to be one where the progress of the individual is not unduly fettered by regulations and restrictions. True, the stream through it is not rapid, but there does not appear any very good reason why an enterprising worker possessing brains and grit should not, provided he has opportunity, derive such benefit from suitable technical education as will be of value to him and to the industry.

It need scarcely be said that the industry can help with material, probably with equipment and apparatus. Certain industries have found it worth while—in some cases on a large scale—to supply money ; they have found it a paying proposition. It is certain that an industry like yours, where so much depends upon a knowledge of the raw material and its various treatments, would also find financial help to technical education a sound business proposition.

In a certain part of this country, coal owners subscribe one-tenth of a penny per ton of raw material raised and in consequence a highly efficient educational institution is maintained. Perhaps some of you would be astonished to find what one-tenth of a penny per ton would mean for your industry. It could do much to encourage education and research. There exist opportunities in certain of the provisional Universities for men who have means and time at their disposal to undergo instruction and training in connection with the refractories industry. There have been few such opportunities in Technical Schools. For that reason pardon a reference to the interesting attempt which has just started at Brierley Hill to provide suitable instruction in refractories; its success will be determined largely by the amount of practical support it receives from the industry, and the amount of practical sympathy the industry extends to the students.

DISCUSSION.

Lt.-Col. C. W. Thomas.—We are very much indebted to Mr. Hefford for coming here to-day and bringing such a paper before us. If I may say so, Mr. Hefford is practically the only official person I have so far met, who has taken any real interest in the application of technical knowledge to the refractory materials industry, and whatever success may attend the technical classes at Brierley Hill, that have been set up by the Staffordshire County Council, will be largely due to the backing which Mr. Hefford has given to the scheme from its inception. What he has said this morning is, I think, no more than the bare truth. As he says in his paper, this is not, perhaps, either the time or the place to go into the details of the problem, because everyone must realise how extraordinarily difficult it is to adapt any scheme of technical education to a particular industry, and especially is this the case when you are dealing with it for the first time. But if the members of this section who are also members of the refractory materials industry of the Stourbridge district will bear in mind what Mr. Hefford has said, I feel quite sure that the success of technical education for the workers will be attained. The question has been tackled to some extent by people in other districts. I am not acquainted with the details of what they have done, but, speaking from the results of my own experience, I can safely say that the advantages to be got from educating the workers, even if you only get just a few of them to react favourably to the treatment, are very considerable, and well worth any amount of trouble and support from the manufacturers' point of view, both financial and otherwise. I am very glad that Mr. Hefford came to give this paper, because it is the first time that the matter has been approached in this way in our particular meetings. I hope it will not be the last paper of its kind, and that in future very much more attention will be given to this problem.

PROFESSOR COBB:—(Communicated) Speaking from considerable inside experience of the refractories industry and as a teacher who has grappled with the subject under discussion, I am glad to have the opportunity of endorsing everything that Mr. Hefford has said as to the paramount necessity of laying a sound foundation of the basal sciences in the minds of students. There is a tendency to believe at times that it is possible, by some sort of process not described or understood, to give a student some prepared quintessence of technical knowledge which will place him in quite a commanding position as regards information and competence in a short time. The remarkable thing is, that when such intensive training is desired, it is nearly always by students whose general mental equipment is below and not above the average. The refractories industry is second to none in the demands that it makes at every turn upon trained reason and an understanding of scientific fundamentals, as well as upon carefully acquired information which can at the best be only gradually accumulated. A thorough knowledge of the refractories industry demands work's experience, but how far a man can go when he gets that work's experience will be determined, partly, it is true, by his practical instincts, but also, to an extent which is increasing daily, by the scientific and technical training which he has received before giving up all his time to work's practice.

XV.—The Crazing of English Earthenware.

By A. Heath.

Introduction.

CRAZING, one of the most insidious faults experienced in earthenware manufacture, has, naturally, received considerable attention from the students of technical pottery. Of a consequence, this matter has been the subject of many deliberations, and certain rules have been formulated, which purport to circumscribe the possibilities of crazing. It is with diffidence, therefore, that consideration of this subject is again brought under the eye of the Society.

The common practice of the English earthenware manufacturer has been confined to the use of a certain type of body, which matures at a fairly low biscuit temperature, and a glaze which, in general, gives good results at a still lower temperatute. If the body materials are controlled by the use of definite chemical and physical tests, little trouble is experienced, but if, through lack of control, any variation in the composition of these materials is ignored, the "balance" of the body with the glaze is upset, and trouble is encountered. That such variations in the compositions of bodies are constantly arising is shown by a consideration of the innumerable varieties of ball clay and china clay on the market and the selective tests adopted in practice. The test of the "fired" colour of sample clay is doubtless a useful and convenient one; but, as the sole criterion in the selection of a clay, it is a futility, for it may be the direct cause of a decided variation in the composition of the body, and faults not present in the original soon become very apparent.

The work contained in this paper was undertaken in the main with the idea of expressing the limit of variation in the composition of a body in relation to the exhibition of such faults as crazing and peeling with a given glaze. It is not imagined that such an object has been fulfilled, but it is suggested that a method, which will eventually lead to the formulation of a standard, has been indicated.

General.

The conception of the principle underlying the present work was suggested in an authoritative statement, which indicated that the use of a body containing 70 per cent. SiO_2 practically excludes the possibility of crazing. This rule is evidently intended as a standardization for the orthodox earthenware body. The present author, however, while not refuting the utility of such an approximation, decided to investigate factors other than the silica content.

The work of Seger on crazing, and the rules he formulated for its prevention, must be familiar to all students of pottery. This work was subjected to much discussion in America, but the

gist of this criticism is hardly relevent to the present paper. Truss and Stanway attempted work of more immediate value to the English manufacturer. The limitations of this attempt are very much in evidence. The investigators only used one biscuit firing condition; they omitted the composition of the glaze; and further, although they gave the analyses of the materials used, nevertheless, in their calculations, they assumed the ball clay and china clay to be pure clay substance, the felspar pure orthoclase, and the flint pure silica. The analyses showed these substances to be far from pure. However, if the work of these investigators had been continued, it would have been possible to have drawn some of the conclusions of the present paper without necessitating such lengthy trials.

Details of the Trials used in the Present Investigation.

Eighty bodies were made up from the materials, whose compositions are reported in Table I. The diagram (Fig. 1) shows the compositions of these eighty bodies. In order to obtain a wide range of firing conditions, ten trials of each body were taken and

Table 1.

No.	Ball Clay	China Clay	Flint	Felspar	No.	Ball Clay	China Clay	Flint	Felspar	No.	Ball Clay	China Clay	Flint	Felspar
1	48	32	5	15	28	30	20	15	35	55	12	8	30	40
2	48	32	15	5	29	30	20	20	30	56	12	8	40	30
3	42	28	5	25	30	30	20	25	25	57	12	8	50	20
4	42	28	10	20	31	30	20	30	20	58	12	8	60	10
5	42	28	15	15	32	30	20	35	15	59	9	6	5	80
6	42	28	20	10	33	30	20	40	10	60	9	6	12½	72½
7	42	28	25	5	34	30	20	45	5	61	6	4	10	80
8	39	26	5	30	35	24	16	10	50	62	6	4	20	70
9	39	26	10	25	36	24	16	15	45	63	6	4	30	60
10	39	26	15	20	37	24	16	25	35	64	6	4	40	50
11	39	26	20	15	38	24	16	35	25	65	6	4	50	40
12	39	26	25	10	39	24	16	45	15	66	6	4	60	30
13	39	26	30	5	40	24	16	50	10	67	6	4	65	25
14	36	24	5	35	41	24	16	55	5	68	6	4	70	20
15	36	24	10	30	42	21	14	5	60	69	6	4	75	15
16	36	24	15	25	43	21	14	12½	52½	70	6	4	80	10
17	36	24	20	20	44	21	14	27½	37½	71	3	2	10	85
18	36	24	25	15	45	21	14	37½	27½	72	3	2	17½	77½
19	36	24	30	10	46	21	14	47½	17½	73	3	2	22½	72½
20	36	24	35	5	47	21	14	57½	7½	74	3	2	27½	67½
21	33	22	10	35	48	18	12	10	60	75	3	2	32½	62½
22	33	22	15	30	49	18	12	20	50	76	3	2	37½	57½
23	33	22	20	25	50	18	12	30	20	77	3	2	45	50
24	33	22	25	20	51	18	12	60	10	78	3	2	55	40
25	33	22	30	15	52	15	10	5	70	79	3	2	65	30
26	33	22	35	10	53	12	8	10	60	80	3	2	70	25
27	30	20	10	40	54	12	8	20	..					

NOTE.—Nos. 53/58 only add up to 90.

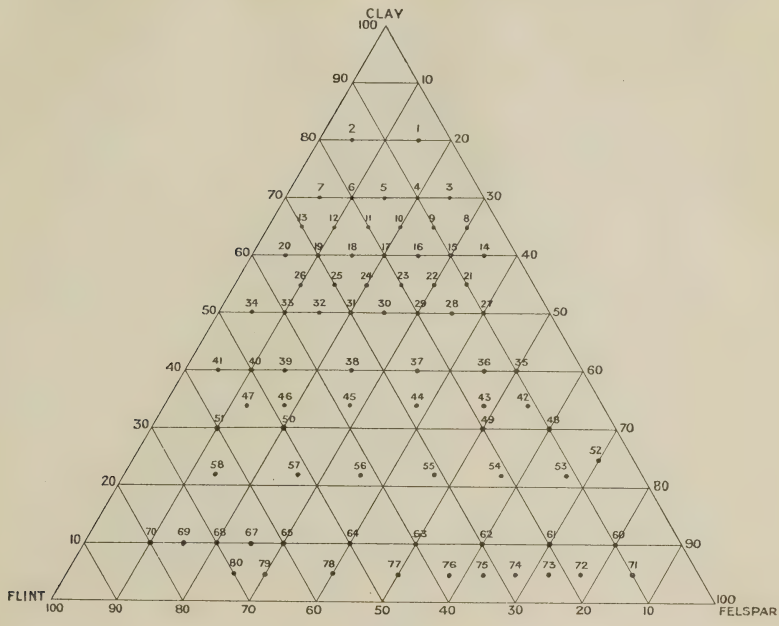


Fig. 1.

two of each batch were fired under similar conditions. Five such firing conditions were thus used. The crazing was examined immediately after the glost firing and then after six or seven week's exposure to the weather. The diagrams (Fig. 2, 3, 4, 5, 6) show the results obtained after firing the biscuit at Cones 04, 01, 2–3, 3–4, 8–9, respectively, the glost in all cases being Cone 01. From these diagrams certain general results may be noted at once :—

Fig. 2. Cone 04. Out of the 80 bodies, 33 were free from crazing on drawing from the oven. Only 5 bodies showed entire absence of the fault after six weeks' exposure. Nos. 39 and 56 crazed subsequently.

Fig. 3. Cone 01. Ordinary Earthenware Biscuit. The results indicate that the safe range has been greatly extended. Nos. 44, 45, 25, 26 and 31 crazed and No. 41 peeled.

Fig. 4. Cone 2–3. Earthenware Biscuit. In general the safe range has been extended still more. It must be noted, however, that a few bodies (25–26 ; 31–33) which showed no crazing at Cone 01, cannot be included in the safe range.

Fig. 5. Cone 3–4. Hard Earthenware Biscuit. 11 other bodies enter the safe range, viz., 21–22 ; 27–34 ; 61–62. 26 crazed since.

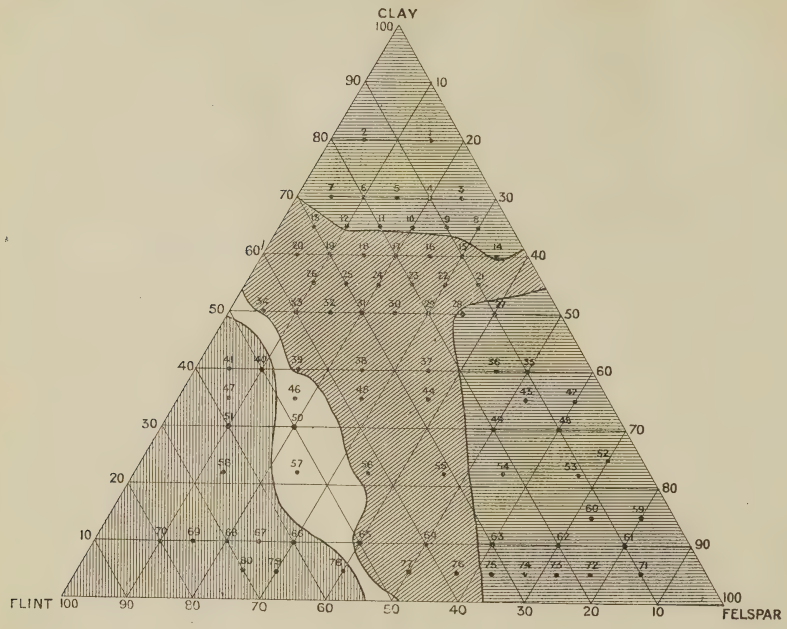


Fig. 2.

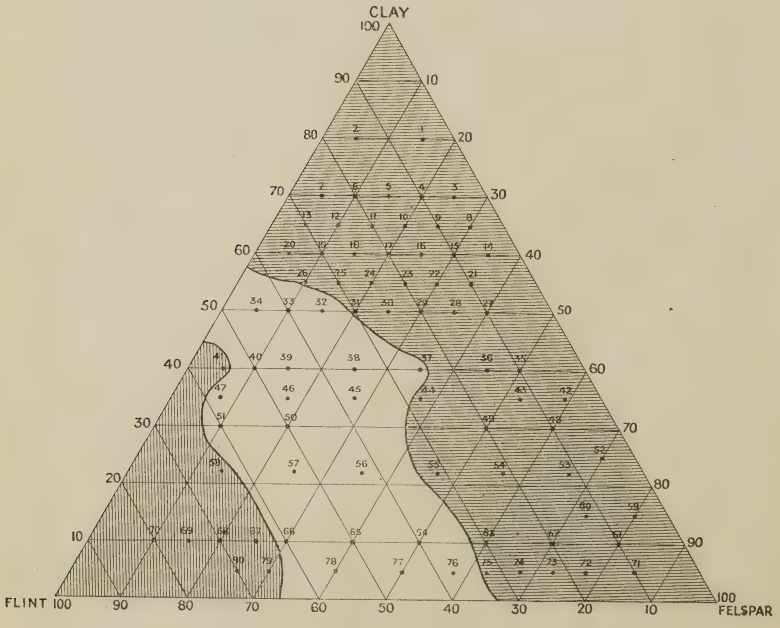


Fig. 3.

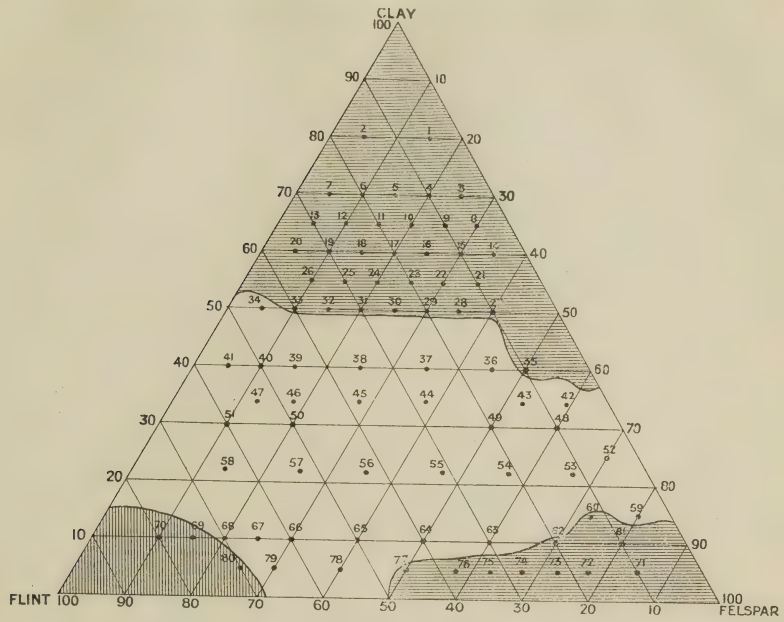


Fig. 4.

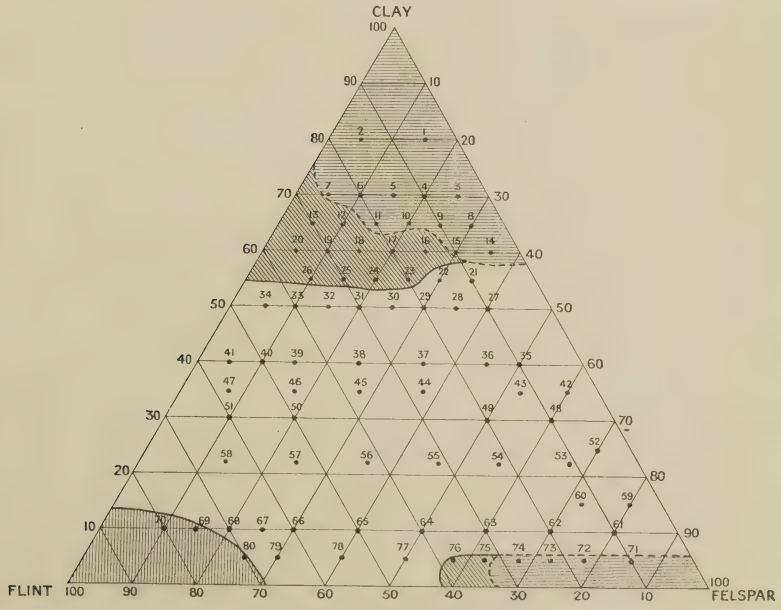


Fig. 5.

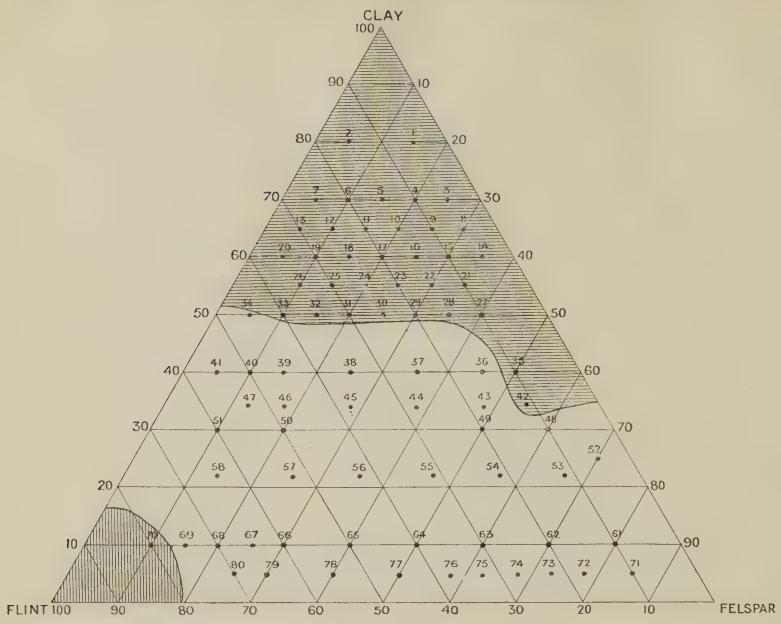


Fig. 6.

Fig. 6. Cone 8–9. While the whole of the peeling area, with one exception, is rendered safe; and, further, the high felspar crazing area has also been eliminated, the crazing of the high clay areas has actually increased. Thus, it is noted, that 21–22, 27–33, which were safe at Cone 3–4, have crazed badly at Cone 8–9.

A Method of Standardisation.

The above diagrammatic representation of these results is, of course, only applicable where bodies used are made up from materials of the compositions indicated in Table 1. There is little doubt that, if materials of different compositions were used, many of the bodies, which are included in the "areas of safety" would have no legitimate right to be placed in such a category, whilst some, now in the danger zone, would be transferred to the safe zone. The possibility of interpreting the results according to the principle of the ultimate composition of the body suggests itself. Thus, considering the analysis of each of the materials used, we at once see that such analyses may be conveniently resolved in terms of silica, alumina and bases. Such a resolution admits of easy application in the comparison of bodies and, moreover, indicates at a glance any possible relationship between silica-content and liability to crazing and peeling. The conversion of the recipes of each of the 80 bodies into terms of silica, alumina and bases is merely a matter of calcula-

tion. Since lime is understood to have a particular influence on the property of crazing, it was decided further to resolve the bases in terms of alkalies and lime. A tabular scheme has been adopted and shows at a glance the compositions of all the bodies after firing in terms of silica, alumina and bases. Further, the contractions and porosities of these bodies, after the specified firings, have been indicated. On the basis of these figures diagrams have been constructed. It is emphasized that the percentages of SiO_2, Al_2O_3 and bases used in the diagrams are those of the fired body. Since the "Loss on ignition" term is known, it is quite easy to calculate the percentages of these constituents in the unfired mixture. This is important, since the rule, mentioned in an earlier paragraph, refers to the unfired material.

Interpretation of Results on the Basis of this Method.

The results obtained by this method of interpretation can now be examined.

Fig. 7. This shows the position of the 80 bodies on the full triangle of bases, alumina and silica. The area showing the compositions of the examined bodies is very small and, consequently, the representation of this area has been enlarged.

Fig. 8. Cone 04. It is noted at once that here, all bodies free from crazing and peeling have silica contents varying from 73 per cent. to 79 per cent. In certain cases, it is indicated that, of bodies having the same silica content, some appear to be safe, others unsafe. It is suggested that the variation in the ratio of bases to alumina forms a criterion of crazing.

Fig. 9. Cone 01. This diagram indicates that, with three exceptions, no body containing less than 70 per cent. SiO_2 is safe. There are, however, quite a number over 70 per cent. SiO_2 which are unsafe.

Fig. 10. Cone 2–3. At this fire, it is found that quite a number of bodies, with as low a silica content as 63 per cent., are safe, but they are of such a composition from the point of view of the bases-content as to render them unsuitable for practical purposes. Quite a number of bodies containing up to 77 per cent. SiO_2 are unsafe, *e.g.*, Nos. 71–76, 42–43, 48, 52–55, 59–66.

Fig. 11. Cone 3–4. Here again, it is noted that some of the lower SiO_2 bodies have been rendered safe. In the main, however, the percentage of bases makes them unsuitable for practical purposes.

Fig. 12. Cone 8–9. At this fire, quite a number of bodies, which were safe at Cone 3–4, have become unsafe. But a number unsafe at Cone 3–4 have entered the safe area. In addition, the peeling area, with one exception, had been eliminated.

In general, the effect of fire may be stated in the terms—easy fire crazes, ordinary fire is safe, extra hard fire crazes.

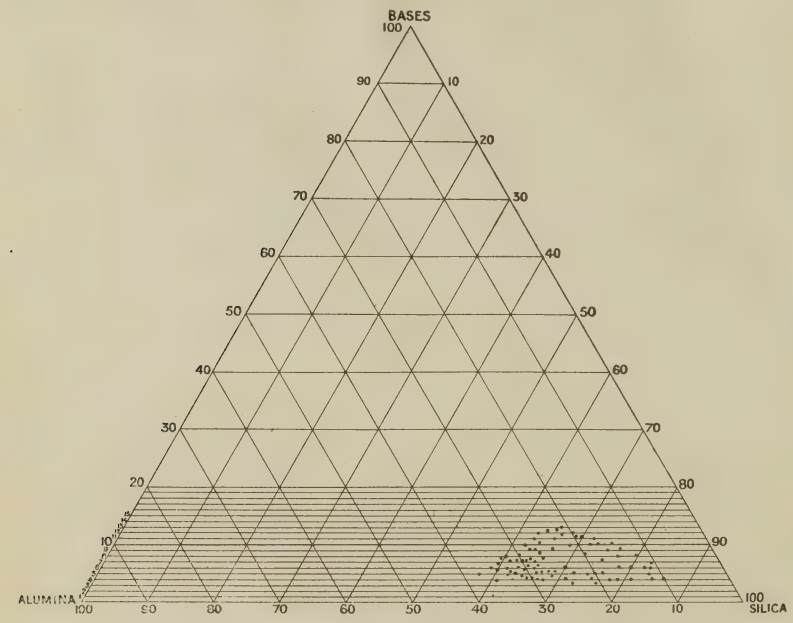


Fig. 7.

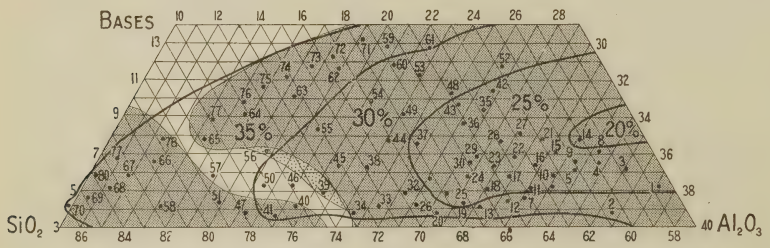


Fig. 8.

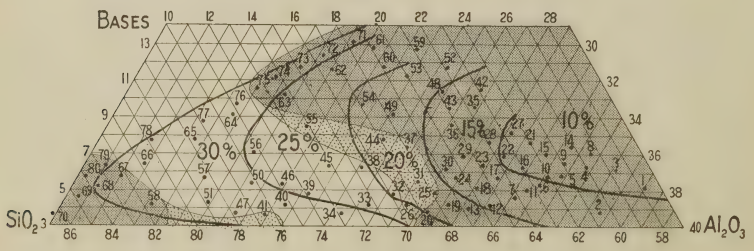


Fig. 9.

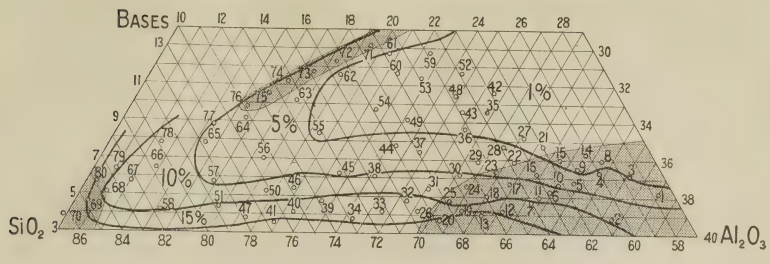


Fig. 10.

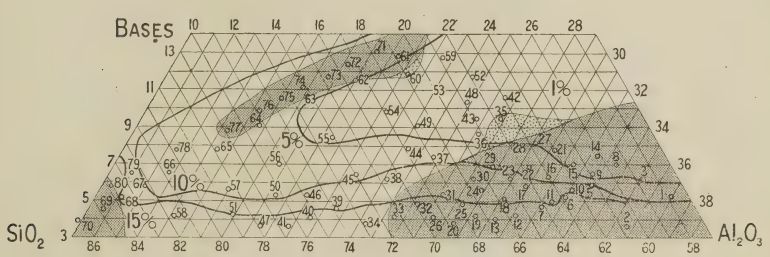


Fig. 11.

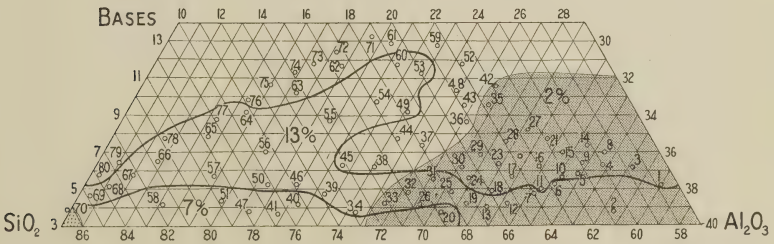


Fig. 12.

CONSIDERATIONS ARISING IN ACTUAL MANUFACTURE.

In the main, the previous remarks have only extended to a consideration of the silica-content and crazing. The potter, however, must have a practical body; one which will present no difficulty in making, drying and handling when dry; one which will withstand distortion during the biscuit fire and will take the quicker glost fire without risk. Obviously many of the bodies are ruled out, for it is essential to have enough clay to give plasticity and enough bases to give the required vitrification without rendering the body too fusible. Thus, Fig. 10 shows that those bodies containing less than 70 per cent. of SiO_2, and indicating no crazing, are very liable to easy fusibility. Further, Fig. 4 indicates that the clay content is such as to anticipate decreased plasticity.

A close examination of the diagrams shows that the body containing :

Bases, 6·1 per cent.
Alumina, 19·5 ,,
Silica, 74·4 ,,

is an ideal body from the point of view of freedom from crazing and peeling. It is not suggested that such a body is ideal for practical purposes ; nevertheless, given the required practical properties, the nearer this composition the greater the margin of safety. The clay-flint-felspar diagram gives the recipe of the body as :

30 Clay (18 Ball Clay, 12 China Clay)
25 Felspar
45 Flint,

using the materials of the compositions given in Table 1. On the face of it, such a body would appear to be too low in clay and much too high in felspar. However, the same composition can be obtained by the following recipe :

30 Ball Clay,
15 China Clay,
20 Stone,
35 Flint,

by using certain commercial brands of these ingredients. Such a mixing corresponds closely with the general conception of an English earthenware body.

On the basis of the foregoing ideal composition, the following statement of fact can be made.

(1). If the SiO_2 is raised at the expense of Al_2O_3 up to 79 per cent. SiO_2 and 15 per cent. Al_2O_3, the body is still safe. If, however, the SiO_2 is further increased at the expense of Al_2O_3, peeling is noted. Example :—

			Safe.	Peeling noted.	
(51)	30 Clay	Bases	4½ per cent.	4·21 per cent.	20 Clay
	50 Flint	Al_2O_3	16·89 ,,	14·19 ,,	60 Flint
	20 Felspar	SiO_2	78·93 ,,	81·61 ,,	10 Felspar

(2). If the SiO_2 is raised at the expense of the bases, peeling is again noted. Example :—

		Safe.	Peeling noted.	
32 Clay	Bases	5·0 per cent.	3·5 per cent.	25 Clay
55 Flint	Al_2O_3	18·0 ,,	18½ ,,	65 Flint
13 Felspar	SiO_2	77·0 ,,	78·5 ,,	10 Felspar

(3). If the Al_2O_3 is raised at the expense of SiO_2, crazing is noted. Example :—

			Safe.	Crazing noted.	
(41)	40 Clay	Bases	6·4 per cent.	6·15 per cent.	50 Clay
	55 Flint	Al_2O_3	21·52 ,,	22·99 ,,	45 Flint
	5 Felspar	SiO_2	72·04 ,,	70·73 ,,	5 Felspar

(4). If the Al_2O_3 is raised at the expense of the bases, crazing is again noted. Example :—

		Safe.	Crazing noted.	
35 Clay	Bases	5·4 per cent.	3·5 per cent.	50 Clay
47½ Flint	Al_2O_3	19·7 ,,	22·0 ,,	45 Flint
17½ Felspar	SiO_2	74·9 ,,	7·45 ,,	5 Felspar

(5). If the bases are raised at the expense of Al_2O_3, peeling is noted. Example :—

		Safe.	Peeling noted.	
22 Clay	Bases	5·0 per cent.	7·8 per cent.	10 Clay
58 Flint	Al_2O_3	15·0 per cent.	12·2 ,,	55 Flint
15 Felspar	SiO_2	80·0 ,,	80·0 ,,	35 Felspar

(6). If the bases are raised at the expense of SiO_2 crazing is noted. Example :—

		Safe.	Crazing noted.	
22 Clay	Bases	6·0 per cent.	9·0 per cent.	10 Clay
50 Flint	Al_2O_3	17·0 ,,	17·0 ,,	35 Flint
28 Felspar	SiO_2	77·0 ,,	74·0 ,,	55 Felspar

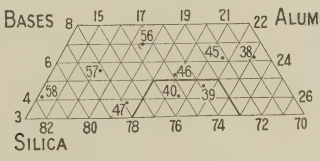


Fig. 13.

The diagram (Fig. 13) shows graphically the range of bodies safe from crazing and peeling. Such bodies give a wide range of firing conditions varying from Cone 04 to Cone 9. The porosities after such heat work may vary from 0·7 per cent. to 40 per cent.

Using materials of the composition in Table 1, a batch of 5 dozen plates as made up according to the recipe :—

18 Ball Clay,
12 China Clay,
25 Felspar,
45 Flint,

which, as already indicated, is the ideal composition from a point of view of freedom from crazing and peeling. The object of this work was to test the practical value of such a body. No making difficulties were encountered. Earthenware biscuit fire (easy and hard) gave good results. Those fired in earthenware glost dottled showed signs of indentations due to the thimbles used for placing. The test for crazing showed remarkable results, noted after the plates had stood in nitre solution for 12 days. Those fired in biscuit dottled came out of the oven in a very distorted shape. The general conclusion from the experiments is that, from a practical point of view, such a composition is impracticable with the glaze used.

Porosity.

The porosity of a fired body is intimately connected with three variables encountered in manufacture, viz. :—

(1). Composition of a body;
(2). Degree of fire to which the body has been subjected;
(3). Degree of fineness of the materials used in the body, and the method of making.

Nos. 1 and 2 formed the basis of this investigation. The importance of the degree of fineness has been already recognised. To exemplify the relation between porosity and crazing, Body No. 33 may be considered. The composition of this body is indicated as :

Bases,	4·26 per cent.	The composition of this body indicates a liability to crazing. However, it affords a ready illustration of the influence of porosity on this fuel.
SiO_2	71·25 ,,	
Al_2O_3,	24·44 ,,	

Now,

at a porosity of	12·92 per cent.,	the body was found to be safe	(D)
,, ,, ,,	15·79 ,,	,, ,, ,, ,, ,, craze	(C)
,, ,, ,,	0·30 ,,	,, ,, ,, ,, ,, ,,	(E)

In passing, it may be mentioned that the porosity of goods contained in the same saggar varies much more than is generally recognised. Even in the same bung it may vary considerably. The following case will illustrate this :

Top plate	16·27 per cent.	
No. 10,	14·61 ,,	
No. 20,	18·33 ,,	
No. 21,	17·14 ,,	centre
	17·41 ,,	fire side
	15·90 ,,	Off fire side

The Effect of Lime.

The effect of lime on the possibility of crazing is important, and although it has not been previously defined, it has always been appreciated. The charts show the percentage of lime in all the bodies, and some conclusion, naturally not too well defined, may be drawn from these charts. A few extra trials, however, were made with the object of indicating this effect. Considering the two bodies :—

	Alk.	CaO	Al_2O_3	SiO_2
No. 48.	9·81	0·71	24·81	64·70
No. 85.	8·27	1·84	24·86	64·99

It is noted that No. 48 was quite safe at ordinary earthenware fire temperatures, whereas, No. 85 crazed badly at this fire and under higher firing conditions. Further, it is stated, while the glaze to suit the high percentage of bases eliminated crazing in No. 48, it failed to do so in the presence of a high lime content.

The Glaze.

So far no mention has been made concerning the composition of the glaze. The author considers that the bulk of crazing is due entirely to variations in body composition. Generally speaking, the range of composition of the glaze is very narrow and the ingredients are not so liable to variation as in the case of bodies. It must be emphasized, however, that some care must be exercised in the choice of the right glaze for the particular body we use. In this work the glaze used had the composition :—

$$\left.\begin{matrix} 0{\cdot}070\ K_2O \\ 0{\cdot}233\ Na_2O \\ 0{\cdot}400\ CaO \\ 0{\cdot}290\ PbO \end{matrix}\right\} \quad 0{\cdot}251\ Al_2O_3 \quad \left\{\begin{matrix} 3{\cdot}164\ SiO_2 \text{(Mol wt. 351)} \\ 0{\cdot}402\ B_2O_3 \end{matrix}\right.$$

From practical experience, it was assumed that such a glaze would show little liability to crazing with an ordinary body.

With regard to the problem of remedying crazing by the alteration of the glaze, the well known Seger rules would apply, and in a small series of confirmatory tests, the desired results were obtained, viz. :—

For peeling—too high Silica in body—reduce SiO_2 in glaze.
For crazing— ,, low ,, ,, ,, raise ,, ,, ,,

A Safe Body.

The portion within the thick lines on the previous safe body diagram (Fig.) shows the best compositions for safe practical working. In the writer's opinion, No. 40 is the safest in the fired condition, this has a composition indicated by :—

75·24	per cent.	SiO_2
20·59	,,	Al_2O_3
4·18	,,	Bases

Before firing the composition is :

71·10	per cent.	SiO_2
19·50	,,	Al_2O_3
3·97	,,	Bases
5·42	,,	Loss on ignition.

This body gives a safe firing range from Cone 01 to Cone 9, the porosity varying from 27·63 per cent. to 2·25 per cent. It meets with the requirements of practical potting, both as regards plasticity and safety during fire up to, say, Cone 6, which is the limit required in the hardest earthenware fire. Basing the constituents of the ingredients on Table 1, this body has a recipe corresponding to :—

40 Clay,
50 Flint,
10 Felspar.

TABLE 2. *Actual Quantity of each Ingredient present.*

No.	ALKALIES					LIME					ALUMINA					SILICA					
	Ball	China	Flint	Fel-spar	Total	Ball	China	Flint	Fel-spar	Total	Ball	China	Flint	Fel-spar	Total	Ball	China	Flint	Fel-spar	Total	Loss
1	·984	·454	·062	2·197	3·697	·787	·102	·069	·0525	1·0105	17·985	12·521	·225	2·985	33·716	22·78	15·216	4·56	9·735	52·291	19·286
2	·984	·454	·186	·732	2·356	·787	·102	·207	·0175	1·1135	17·985	12·521	·675	·995	32·176	22·78	15·216	13·68	3·245	54·921	10·434
3	·861	·454	·062	3·666	5·043	·688	·102	·069	·0875	·9465	15·751	2·521	·225	4·975	33·471	19·92	15·216	4·56	16·225	55·931	10·434
4	·861	·397	·124	2·931	4·313	·688	·090	·138	·0700	·986	15·75	10·948	·450	3·980	31·128	19·93	13·314	9·12	12·980	55·344	8·229
5	·861	·397	·186	2·197	3·641	·688	·090	·207	·0525	1·037	15·75	10·948	·675	2·985	30·358	19·93	13·314	13·68	9·735	56·659	8·305
6	·861	·397	·248	1·467	2·973	·688	·090	·276	·0350	1·089	15·75	10·948	·900	1·990	29·588	19·93	13·314	18·24	6·49	57·974	8·376
7	·861	·397	·310	·733	2·301	·688	·090	·345	·0175	1·1405	15·75	10·948	1·125	·995	28·818	19·93	13·314	22·80	3·245	59·289	8·452
8	·799	·369	·062	4·39	5·620	·639	·083	·069	·105	·896	14·625	10·166	·225	5·970	30·986	18·52	12·366	4·56	19·47	54·916	7·582
9	·799	·369	·124	3·666	4·958	·639	·083	·138	·087	·947	14·625	10·166	·450	4·975	30·216	18·52	12·366	9·12	16·225	56·231	7·648
10	·799	·369	·186	2·931	4·285	·639	·083	·207	·070	·999	14·625	10·166	·675	3·980	29·446	18·52	12·366	13·68	12·98	57·546	7·724
11	·799	·369	·248	2·197	3·613	·639	·083	·276	·0525	1·0505	14·625	10·166	·900	2·985	28·676	18·52	12·366	18·24	9·735	58·861	7·800
12	·799	·369	·310	1·467	2·945	·639	·083	·345	·035	1·102	14·625	10·166	1·125	1·990	27·906	18·52	12·366	22·80	6·49	60·176	7·871
13	·799	·369	·372	·733	2·273	·639	·083	·414	·0175	1·1535	14·625	10·166	1·350	·995	27·136	18·52	12·366	27·36	3·245	61·491	7·947
14	·738	·341	·062	5·133	6·274	·59	·077	·069	·122	·858	13·495	9·384	·225	6·965	30·069	17·08	11·412	31·92	22·715	55·767	7·032
15	·738	·341	·124	4·390	5·593	·59	·077	·138	·105	·910	13·495	9·384	·450	5·970	29·299	17·08	11·412	4·56	19·47	57·082	7·116
16	·738	·341	·186	3·666	4·931	·59	·077	·207	·087	·961	13·495	9·384	·675	4·975	28·529	17·08	11·412	9·12	16·225	58·397	7·182
17	·738	·341	·248	2·931	4·258	·59	·077	·276	·070	1·013	13·495	9·384	·900	3·980	27·759	17·08	11·412	13·68	12·98	59·712	7·258
18	·738	·341	·310	2·197	3·586	·59	·077	·345	·0525	1·0645	13·495	9·384	1·125	2·985	26·989	17·08	11·412	18·24	9·735	61·027	7·334
19	·738	·341	·372	1·467	2·918	·59	·077	·414	·035	1·116	13·495	9·384	1·35	1·990	26·219	17·08	11·412	22·80	6·49	62·342	7·405
20	·738	·341	·434	·733	2·246	·59	·077	·483	·0175	1·1675	13·495	9·384	1·575	.995	25·449	17·08	11·412	27·36	3·245	63·657	7·748
21	·676	·312	·124	5·133	6·245	·541	·07	·138	·122	·871	12·375	8·602	·45	6·965	28·392	15·67	10·466	31·92	22·715	57·971	6·521
22	·676	·312	·186	4·390	5·564	·541	·07	·207	·105	·923	12·375	8·602	·675	5·970	27·622	15·67	10·466	9·12	19·47	59·286	6·605
23	·676	·312	·248	3·666	4·902	·541	·07	·276	·087	·974	12·375	8·602	·900	4·975	26·852	15·67	10·466	13·68	16·225	60·601	6·671
24	·676	·312	·310	2·931	4·229	·541	·07	·345	·070	1·026	12·375	8·602	1·125	3·980	26·082	15·67	10·466	18·24	12·98	61·986	6·677
25	·676	·312	·372	2·197	3·537	·541	·07	·414	·0525	1·0775	12·375	8·602	1·35	2·985	25·312	15·67	10·466	22·80	9·735	63·231	6·843
26	·676	·312	·434	1·467	2·889	·541	·07	·483	·035	1·129	11·25	8·602	1·575	1·990	24·542	15·67	10·466	27·36	6·49	64·546	6·894
27	·615	·284	·124	5·861	6·884	·492	·064	·138	·140	·834	11·25	7·82	·45	7·960	27·480	14·24	9·51	31·92	25·96	58·830	5·972
28	·615	·284	·186	5·133	6·218	·492	·064	·207	·122	·885	11·25	7·82	·675	6·965	26·710	14·24	9·51	9·12	22·715	60·145	6·042
29	·615	·284	·248	4.391	5·537	·492	·064	·276	·105	.937	11·25	7·82	·90	5·97	25·94	14·24	9·51	13·68	19·47	61·46	6·126
30	·615	·284	·31	3·666	4·875	·492	·064	·345	·087	·988	11·25	7·82	1·125	4·975	25·17	14·24	9·51	18·24	16·225	62·775	6·192
31	·615	·284	·372	2·931	4·202	·492	·064	·414	·070	1·04	11·25	7·82	1·35	3·980	24·40	14·24	9·51	22·80	12·98	64·09	6·228
32	·615	·284	·434	2·197	3·53	·492	·064	·483	·0525	1·091	11·25	7·82	1·575	2·985	23·63	14·24	9·51	27·36	9·735	65·405	6·344
33	·615	·284	·496	1·467	2·862	·492	·064	·552	·035	1·143	11·25	7·82	1·80	1·990	22·86	14·24	9·51	36·48	6·49	66·72	6·415
34	·615	·284	·558	·733	2·19	·492	·064	·621	·0175	1·194	11·25	7·82	2·025	·995	22·09	14·24	9·51	41·04	3·245	68·035	6·491
35	·492	·227	·124	7·325	8·168	·393	·051	·138	·175	·757	9·0	6·256	·45	9·95	25·656	11·39	7·608	9·12	32·45	60·568	4·851
36	·492	·227	·186	6·591	7·496	·393	·051	·207	·1575	·808	9·0	6·256	·675	8·955	24·886	11·39	7·608	13·68	29·205	61·883	4·927
37	·492	·227	·31	5·133	6·162	·393	·051	·345	·1225	·911	9·0	6·256	1·125	6·965	23·346	11·39	7·608	22·80	22·715	64·513	5·068
38	·492	·227	·434	3·666	4·819	·393	·051	·483	·087	1·014	9·0	6·256	1·575	4·975	21·806	11·39	7·608	31·92	16·225	67·143	5·218
39	·492	·227	·558	2·197	3·474	·393	·051	·621	·0525	1·117	9·0	6·256	2·025	2·985	20·266	11·39	7·608	41·04	9·735	69·773	5·370
40	·492	·227	·62	1·467	2·806	·393	·051	·691	·035	1.169	9·0	6·256	2·25	1·990	19·496	11·39	7·608	45·60	6·49	71·088	5·441

TABLE 2—*contd.* *Actual Quantity of each Ingredient present.*

No.	ALKALIES					LIME					ALUMINA					SILICA					
	Ball	China	Flint	Fel-spar	Total	Ball	China	Flint	Fel-spar	Total	Ball	China	Flint	Fei-spar	Total	Ball	China	Flint	Fel-spar	Total	Loss
41	·492	·227	·682	·733	2·134	·393	·051	·759	·0175	1·22	9·0	6·256	2·475	·995	18·226	11·39	7·608	50·16	3·245	72·403	6·017
42	·43	·199	·062	8·782	9·473	·344	·045	·069	·21	·668	7·875	5·474	·225	11·94	25·514	9·97	6·657	4·56	38·94	60·127	4·218
43	·43	·199	·155	7·665	8·449	·344	·045	·172	·184	·745	7·875	5·474	·562	10·447	24·358	9·97	6·657	11·40	34·072	62·099	4·349
44	·43	·199	·328	5·48	6·437	·344	·045	·379	·131	·899	7·875	5·474	1·237	7·462	22·048	9·97	6·657	25·08	24·337	66·044	4·572
45	·43	·199	·452	4·022	5·103	·344	·045	·517	·096	1·002	7·875	5·474	1·682	5·472	20·503	9·97	6·657	34·30	17·847	68·674	4·718
46	·43	·199	·576	2·565	3·77	·344	·045	·655	·061	1·105	7·875	5·474	2·137	3·482	18·968	9·97	6·657	43·30	11·357	71·284	4·873
47	·43	·199	·70	1·098	2·427	·344	·045	·793	·026	1·208	7·875	5·474	2·587	1·492	17·428	9·97	6·657	52·44	4·867	73·934	5·003
48	·369	·17	·124	8·782	9·445	·29	·038	·138	·21	·681	6·75	4·692	·45	11·94	23·832	8·54	5·706	9·12	38·94	62·306	3·736
49	·369	·17	·248	7·325	8·112	·295	·038	·276	·175	·784	6·75	4·692	·90	9·95	22·292	8·54	5·706	18·24	32·45	64·936	3·876
50	·369	·17	·62	2·931	4·09	·295	·038	·69	·07	1·093	6·75	4·692	2·25	3·98	17·672	8·54	5·706	45·60	12·98	72·826	4·319
51	·369	·17	·744	1·467	2·75	·295	·038	·828	·035	1·196	6·75	4·692	2·70	1·99	16·132	8·54	5·706	54·72	6·49	75·456	4·466
52	·307	·142	·062	10·261	10·772	·246	·032	·069	·245	·592	5·625	3·91	·225	13·93	23·69	7·12	4·755	4·56	45·43	61·865	3·081
53	·246	·113	·124	8·732	9·215	·197	·026	·138	·21	·571	4·5	3·128	·45	11·94	20·018	5·69	3·804	9·12	38·94	57·554	2·642
54	·246	·113	·248	7·325	7·932	·197	·026	·276	·175	·674	4·5	3·128	·90	9·95	18·478	5·69	3·804	18·24	32·45	60·184	2·732
55	·246	·113	·372	5·861	6·592	·197	·026	·414	·14	·777	4·5	3·128	1·35	7·96	16·938	5·69	3·804	27·36	25·96	62·814	2·871
56	·246	·113	·496	4·39	5·245	·197	·026	·552	·105	·880	4·5	3·128	1·80	5·97	15·398	5·69	3·804	36·48	19·47	65·444	3·139
57	·246	·113	·620	2·931	3·91	·197	·026	·69	·07	·983	4·5	3·128	2·25	3·98	13·858	5·69	3·804	45·60	12·98	68·074	3·155
58	·246	·113	·744	1·467	2·57	·197	·026	·828	·035	1·086	4·5	3·128	2·70	1·99	12·318	5·69	3·804	54·72	6·49	70·704	3·322
59	·184	·085	·062	11·724	12·055	·147	·019	·069	·28	·515	3·75	2·346	·225	15·82	22·241	4·27	2·853	4·56	51·92	63·603	1·586
60	·184	·085	·155	10·622	11·046	·147	·019	·172	·253	·591	3·75	2·346	5·62	14·427	21·085	4·27	2·853	11·40	47·552	66·075	1·203
61	·123	·057	·124	11·724	12·028	·098	·013	·138	·28	·529	2·25	1·564	·45	15·92	20·184	2·85	1·902	9·12	51·92	65·792	1·467
62	·123	·057	·248	10·261	10·689	·098	·013	·276	·245	·632	2·25	1·564	·90	13·93	18·644	2·85	1·902	18·24	45·43	68·522	1·513
63	·123	·057	·372	8·732	9·284	·098	·013	·414	·21	·735	2·25	1·564	1·35	11·94	17·104	2·85	1·902	27·36	38·94	71·052	1·913
64	·123	·057	·496	7·325	8·001	·098	·013	·552	·175	·838	2·25	1·564	1·8	9·95	15·564	2·85	1·902	36·48	32·45	73·682	1·915
65	·123	·057	·62	5·861	6·661	·098	·013	·690	·14	·941	2·25	1·564	2·25	7·96	14·024	2·85	1·902	45·60	25·96	76·312	2·062
66	·123	·057	·744	4·39	5·314	·098	·013	·828	·105	1·044	2·25	1·564	2·7	5·97	12·684	2·85	1·902	54·72	19·47	78·942	2·016
67	·123	·057	·806	3·666	4·652	·098	·013	·897	·087	1·095	2·25	1·564	2·925	4·975	11·714	2·85	1·902	59·28	16·225	80·257	2·282
68	·123	·057	·868	2·931	3·979	·098	·013	·966	·07	1·147	2·25	1·564	3·15	3·98	10·944	2·85	1·902	63·84	12·98	81·572	2·673
69	·123	·057	·93	2·197	3·307	·098	·013	1·035	·0525	1·198	2·25	1·564	3·375	2·985	10·174	2·85	1·902	68·40	9·735	82·887	2·434
70	·123	·057	·992	1·467	2·639	·098	·013	1·104	·035	1·25	2·25	1·564	3·60	1·99	9·404	2·85	1·902	72·96	6·49	84·202	2·505
71	·061	·028	·124	12·456	12·669	·049	·006	·138	·2975	·49	1·125	·782	·45	16·915	19·272	1·424	·951	9·12	55·165	66·660	0·909
72	·061	·028	·217	11·353	11·669	·049	·006	·241	·271	·567	1·125	·782	·782	51·422	18·111	1·424	·951	15·96	50·297	68·632	1·021
73	·061	·028	·281	10·622	10·992	·049	·006	·310	·253	·618	1·125	·782	1·012	14·427	17·346	1·424	·951	20·52	47·052	69·947	1·097
74	·061	·028	·341	9·887	10·317	·049	·006	·379	·236	·670	1·125	·782	1·237	13·432	16·576	1·424	·951	25·08	43·807	71·262	1·175
75	·061	·028	·403	9·157	9·649	·049	·006	·448	·218	·723	1·125	·782	1·462	12·437	15·806	1·424	·951	29·64	40·562	72·577	1·245
76	·061	·028	·464	8·423	8·976	·049	·006	·517	·201	·773	1·125	·782	1·687	11·442	15·036	1·424	·951	34·20	37·317	73·892	1·323
77	·061	·028	·558	7·325	7·972	·049	·006	·621	·175	·850	1·125	·782	2·025	9·95	13·882	1·424	·951	41·04	32·45	75·865	2·078
78	·061	·028	·682	5·861	6·632	·049	·006	·759	·140	·954	1·125	·782	2·475	7·96	12·342	1·424	·951	50·16	25·96	78·495	2·348
79	·061	·028	·806	4·39	5·285	·049	·006	·897	·105	1·057	1·125	·782	2·925	5·97	10·802	1·424	·951	59·28	19·47	81·125	1·731
80	·061	·028	·868	3·666	4·623	·049	·006	·966	·0875	1·108	1·125	·782	3·15	4·975	10·032	1·424	·951	63·84	16·225	82·440	1·797

TABLE 3. *Showing Ingredients in Percentage of Fired Body Bases.*

No.	Alk.	Lime	Total	Alumina	Silica	Total	A		B		D		C		E	
							Contr.	Poros.	Contr.	Poros.	Contr.	Poros.	Contr.	Poros.	Contr.	Poros.
1	4·07	1·17	5·18	37·10	57·63	99·99	6·0	22·05	8·0	10·00	7·0	2·89	8·0	3·34	8·5	·17
2	2·59	1·23	3·82	35·46	60·63	99·91	5·0	26·70	8·0	15·41	8·0	6·15	7·0	12·17	8·0	3·66
3	5·29	·99	6·28	35·11	58·62	100·01	5·5	20·86	8·0	9·00	9·0	·23	8·0	·74	9·0	·15
4	4·65	1·94	6·59	33·59	59·80	99·98	5·5	21·42	8·0	9·64	8·0	2·12	8·5	3·51	9·0	·15
5	3·93	2·00	5·93	32·79	61·21	99·93	5·3	23·45	7·0	12·15	7·0	7·32	7·0	8·09	6·5	·14
6	3·23	2·07	5·30	31·99	62·67	99·96	5·3	25·26	7·0	15·11	8·0	10·50	6·5	11·57	7·5	1·94
7	2·50	2·21	4·71	31·19	64·01	99·91	4·0	26·68	6·0	17·70	8·0	13·45	6·5	14·85	7·5	6·00
8	6·05	·96	7·01	33·48	59·42	99·91	5·0	19·80	8·5	7·71	9·0	·15	8·0	·42	8·0	·07
9	5·37	1·05	6·42	32·67	60·82	99·91	4·5	20·07	8·5	9·38	9·0	·46	8·0	2·45	8·5	·00
10	4·62	1·08	5·70	31·91	62·32	99·93	4·0	21·33	7·5	10·43	8·0	·41	8·5	6·22	8·5	·07
11	3·92	1·14	5·06	31·06	63·75	99·87	3·0	22·47	5·5	13·00	8·0	6·38	7·5	8·42	8·0	·21
12	3·20	1·19	4·39	30·37	65·21	99·97	3·0	27·57	5·0	14·59	7·0	14·57	5·0	16·41	6·0	2·02
13	2·44	1·68	4·12	29·37	66·42	99·91	3·3	25·97	6·0	16·13	7·0	17·82	5·5	12·77	6·6	1·98
14	6·75	·92	7·67	32·31	60·02	100·00	6·0	18·67	9·0	7·03	9·0	·14	8·0	·36	9·0	·07
15	6·03	·98	7·01	31·52	61·42	99·95	5·0	20·00	7·0	9·08	8·0	·21	7·5	1·09	8·0	·00
16	5·30	1·04	6·34	30·69	62·90	99·93	5·0	20·81	6·0	10·39	8·0	1·85	7·5	3·93	8·0	·00
17	4·59	1·08	5·67	29·92	64·42	100·01	4·5	22·61	6·0	12·17	8·0	5·57	7·5	8·05	7·0	·07
18	3·87	1·14	5·01	29·10	65·91	100·03	4·5	24·13	6·0	14·26	7·0	8·86	7·0	10·78	7·0	·14
19	3·15	1·21	4·36	28·31	67·30	99·97	3·3	23·93	5·0	16·82	7·0	11·47	5·9	13·62	6·6	1·45
20	2·43	1·26	3·69	27·48	68·76	99·93	2·0	27·86	3·0	20·21	5·0	16·77	5·0	17·07	8·5	7·11
21	6·68	·93	7·61	30·39	61·99	99·99	4·0	20·12	6·6	10·17	8·0	·28	7·0	·87	8·0	·07
22	5·95	·98	6·93	29·58	63·44	99·95	4·0	20·77	6·0	10·60	8·0	1·36	7·0	4·30	7·0	·00
23	5·25	1·05	6·30	28·79	64·91	100·00	4·0	22·24	6·0	12·98	7·5	4·82	7·0	7·52	7·0	·07
24	4·53	1·11	5·64	27·94	66·36	99·94	4·0	23·87	6·5	15·23	7·0	8·82	6·0	9·15	6·0	·07
25	3·81	1·16	4·97	27·19	67·71	99·87	3·0	25·21	6·0	18·15	7·0	9·29	6·0	11·87	6·0	·56
26	3·11	1·21	4·32	26·32	69·37	100·01	3·0	25·76	5·0	21·09	6·0	12·36	6·0	13·83	8·0	·82
27	7·31	·89	8·20	29·18	62·48	99·86	4·0	21·10	6·5	9·71	7·5	·21	7·0	1·28	8·6	·07
28	6·63	·95	7·58	28·37	63·94	99·89	4·0	21·11	6·0	11·45	7·5	·18	7·0	4·75	8·6	·07
29	5·88	1·01	6·89	27·68	65·33	99·90	3·5	22·41	5·0	13·34	8·0	4·15	7·0	6·52	8·6	·35
30	5·26	1·07	6·33	27·21	66·42	99·96	4·0	26·46	5·0	15·41	8·0	5·85	7·0	8·30	7·3	·07
31	4·52	1·11	5·63	26·04	68·34	100·01	3·5	24·78	5·0	18·03	7·0	8·63	6·0	10·13	6·0	·41
32	3·76	1·17	4·93	25·24	69·84	100·01	2·5	26·00	5·0	20·58	7·0	10·82	5·5	12·61	6·0	·46
33	3·05	1·21	4·26	24·44	71·25	99·95	1·5	27·70	4·0	23·37	7·0	12·92	5·0	15·79	6·0	·30
34	2·34	1·27	3·61	23·57	72·78	99·96	1·5	29·14	3·0	26·05	5·0	15·78	4·5	19·85	6·0	·60
35	8·58	·80	9·38	26·93	63·67	99·98	3·5	22·88	6·0	12·51	9·0	·14	8·0	·79	7·0	·07
36	7·88	·86	8·74	26·17	65·08	99·99	3·5	23·56	6·0	13·19	9·0	·20	8·0	1·20	8·0	·21
37	6·49	·96	7·45	24·55	67·95	99·95	3·5	24·31	5·5	16·11	8·0	3·58	7·5	4·50	8·0	·21
38	5·08	1·07	6·15	22·99	70·73	99·87	2·5	26·34	4·5	20·70	8·0	5·85	6·0	7·92	7·0	·07
39	3·66	1·18	4·84	21·42	73·69	99·95	2·5	28·32	3·0	23·66	8·0	10·98	6·0	10·51	7·0	1·05
40	2·96	1·22	4·18	20·59	75·24	100·01	2·0	27·63	2·5	26·79	6·0	1·75	6·0	14·57	7·0	2·25

TABLE 3—*contd. Showing Ingredients in Percentage of Fired Body Bases.*

No.	Alk.	Lime	Total	Alumina	Silica	Total	A		B		D		C		E.	
							Contr.	Poros.	Contr.	Poros.	Contr.	Poros.	Contr.	Poros.	Contr.	Poros.
41	2·25	1·29	3·54	19·88	76·59	100·01	1·5	30·47	2·0	28·67	6·0	18·22	3·5	18·90	6·5	7·61
42	9·84	·70	10·54	26·64	62·78	99·96	3·5	24·97	6·0	11·01	9·0	·00	9·5	·31	8·0	·07
43	8·83	·79	9·62	25·42	64·91	99·95	3·5	23·94	6·0	12·36	9·0	·07	8·0	·35	8·0	·00
44	6·75	·95	7·70	23·11	69·14	99·95	3·0	26·71	5·3	17·59	9·0	1·77	9·0	1·45	9·0	·13
45	5·35	1·05	6·40	21·52	72·04	99·96	2·0	27·60	4·0	21·35	8·0	4·80	8·0	5·53	7·5	·27
46	3·87	1·17	5·04	19·97	74·97	99·98	1·0	32·74	3·0	24·51	8·0	7·00	6·0	8·76	8·0	·50
47	2·55	1·27	3·82	18·38	77·82	100·02	1·0	31·90	4·0	25·96	7·0	12·71	5·5	16·55	7·0	3·67
48	9·81	·71	10·52	24·81	64·70	100·03	3·0	26·28	6·0	13·88	8·5	·07	9·0	·18	5·0	·12
49	8·43	·81	9·24	23·17	67·51	99·92	3·0	31·62	6·0	16·04	8·5	·73	8·0	·25	5·0	·77
50	4·27	1·13	5·40	18·46	76·08	99·94	1·0	29·69	3·0	36·37	8·0	5·99	8·0	5·37	6·0	·29
51	2·88	1·24	4·12	16·89	78·93	99·94	1·0	31·62	4·0	29·11	8·0	11·37	6·5	10·80	6·0	2·32
52	11·11	·61	11·72	24·43	63·83	99·98	2·5	27·51	6·0	16·04	10·0	·15	9·0	·16		
53	10·53	·65	11·18	22·86	65·91	99·95	3·0	26·77	6·0	17·07	10·0	·14	9·0	·26	0·5	·60
54	9·08	·77	9·85	21·18	68·93	99·96	3·3	27·01	5·0	18·54	8·5	·25	10·0	·28	0·5	1·25
55	7·55	·89	8·44	19·41	72·17	100·02	3·3	30·01	4·0	21·52	9·0	·13	9·0	·23	3·0	1·07
56	6·02	1·01	7·03	17·71	75·26	100·00	3·3	43·83	3·5	23·27	8·0	1·71	9·0	1·29	3·5	1·38
57	4·53	1·14	5·67	15·95	78·31	99·93	0·0	38·67	1·5	30·00	7·5	3·70	9·0	4·73	5·0	·79
58	2·96	1·25	4·21	14·19	81·61	100·01	0·0	33·36	1·0	30·00	8·0	9·82	6·0	11·01	9·0	1·14
59	12·24	·52	12·76	20·46	66·75	99·97	1·0	29·88	4·0	24·84		0·00	10·0	·19	2·5	·15
60	11·18	·60	11·78	21·33	66·88	99·99			5·0	22·09		0·00	10·0	·27	2·0	·66
61	12·22	·54	12·76	22·58	64·61	99·95	1·0	32·42	4·0	23·22			10·5	·26	3·5	·13
62	10·85	·64	11·49	18·94	69·52	99·95	1·0	35·16	3·5	22·66	8·5	·79	10·0	·15	4·6	·20
63	9·44	·76	10·20	17·42	72·35	99·97	0·5	33·03	4·0	23·43	7·0	2·36	7·0	·82	3·0	·12
64	8·15	·86	9·01	15·86	75·12	99·99	0·5	32·19	5·0	33·90	8·0	1·99	7·5	1·48	2·5	1·33
65	6·80	·96	7·76	14·34	77·66	99·76	·5	33·36	1·5	26·53	8·0	2·37	8·5	1·75	1·5	·71
66	5·42	1·06	6·48	12·72	80·72	99·92	·5	32·96	1·5	26·64	9·0	2·75	8·5	2·08	2·0	·47
67	4·73	1·11	5·84	12·00	82·19	100·03	·6	34·93	2·0	30·27	8·0	4·31	8·5	4·63	6·0	·22
68	4·07	1·17	5·24	11·21	83·52	99·97	·5	34·65	1·5	30·27	7·5	7·83	7·0	8·16	7·0	·23
69	3·39	1·23	4·62	10·43	84·92	99·97	·5	31·25	1·0	32·17	6·0	15·43	7·5	13·34	8·0	·35
70	2·70	1·28	3·98	9·64	86·38	100·00	1·0	34·20	1·0	31·24	6·0	18·38	4·0	17·82	7·0	1·94
71	12·77	·49	13·26	19·39	67·39	100·04	0·0	34·77	3·0	28·06	11·0	2·63	11·0	5·73	9·0	·09
72	11·81	·57	12·38	18·28	69·33	99·99	0·0	34·31	3·5	27·11	11·0	2·43	10·5	5·86	8·5	·13
73	11·11	·63	11·74	17·50	70·71	99·95	0·0	34·62	3·3	28·21	11·0	2·66	9·0	3·09	5·3	·09
74	10·44	·68	11·12	16·75	72·08	99·95	0·0	34·93	1·5	27·90			9·0	2·49		
75	9·76	·73	10·49	15·99	73·48	99·96	0·0	36·06	3·0	28·55	10·0	2·59	9·0	2·99	4·0	·21
76	9·08	·78	9·86	15·21	74·88	99·95	0·5	35·37	3·0	28·77	10·0	5·32	9·5	3·60	5·3	·09
77	8·08	·86	8·94	14·09	76·92	99·95	0·5	35·47	3·0	29·39	10·0	3·08	9·0	2·79	6·0	
78	6·72	·95	7·67	12·52	79·76	99·95	0·5	34·23	3·0	29·66	9·0	3·80	9·0	3·59	7·3	·25
79	5·39	1·08	6·47	10·99	82·49	99·96	0·5	35·14	1·5	30·83	8·0	6·73	7·0	8·34	7·0	·10
80	4·72	1·13	5·85	10·18	83·94	99·97	0·5		1·5	32·67	7·0	12·71	6·0	13·20	8·6	·16

Using flint of a normal variety and mixed Cornish Stone in the place of felspar, the mixing can be stated as :—

26 Ball Clay,
22 China Clay,
19 Stone,
33 Flint.

The Effect of Variation in the Composition of the Body Materials.

To show that the alteration of composition of only one material in the body mixing may cause trouble, earthenware bodies were made up, using one recipe, but introducing 64 different varieties of china clay. Fired at ordinary earthenware biscuit and glost temperatures, both crazing and peeling were noted; *i.e.*, four crazed, and two peeled.

The body in this case was : 24 Ball Clay,
28 China Clay,
30 Flint,
18 Stone.

On analysis the china clays showed :

	Standard.	Peeled.	Crazed.
SiO_2	47·56	85·13	51·10
TiO	—	0·44	0·50
Al_2O_3	38·50	7·00	33·08
Fe_2O_3	0·62	0·08	0·56
CaO	0·29	0·50	1·22
MgO	0·03	0·11	0·49
K_2O	1·32	0·56	0·84
Na_2O	0·10	0·54	0·56
Loss	12·02	5·26	11·60

If, then, the alteration in composition of one material will give such different results, how much more may we expect trouble if the composition of four materials varied.

The remarks of Mr. Maddock made at a recent meeting of the American Ceramic Society form a particularly apposite conclusion to this paper : "If you have the right body," said Mr. Maddock, "you will have no crazing—provided your glaze is right."

I would like to place on record my appreciation of services rendered by Mr. A. T. Green and the Empire Porcelain Company in connection with this work.

DISCUSSION.

Mr. H. E. Wood:—You have heard what Mr. Heath has to say on the subject of crazing. For my own part I would like to add something to Mr. Maddock's remarks which Mr. Heath has quoted in his concluding sentence. I think it is quite possible that you may have a theoretically perfect body and glaze, but what you require is a perfect set of workmen around you on your works in order to put your perfect recipes into effect. To my mind the greater number of troubles that we encounter in the Potteries are due not to imperfect recipes but to the fact that we do not get into our bodies and glazes just what we are supposed to get. The variations which we get in our clays, flint, and stone from time to time, through variations in the seams and preparations, also alterations of grinding and calcining, have much to do with the ultimate composition of the body, and in all cases where mistakes are made the effect is two-fold; *e.g.*, we increase the proportion of one material which it is desirable not to increase, and at the same time we reduce the proportion of another material which will not stand being reduced. Sometimes things which seem to be remarkably small are the really important things. We are very grateful to Mr. Heath for the amount of trouble that he has taken in the preparation of this paper—an amount of trouble which many of us are not prepared to take. Many of the lines of thought which he has opened up should be considered by all of us very seriously. I am of the opinion that no mere writing down of figures on a slate or the entry of something into a book will ever make us really safe from these two old snags of ours—crazing and peeling.

Dr. J. W. Mellor:—I have been very interested in Mr. Heath's paper and am appalled at the number of experiments he has made—something like 5,000. I have not had time to grasp the meaning of his results. I may never be able to do so. The subject is very complex. While listening to his paper, I imagined his ball clay to be just a little out of the ordinary. I also thought that his calculation of felspar into equivalent stone may or may not be valid. I do not know. He gets a 14·6 and an 18·33 per cent. porosity for plates in the same saggar. This is extraordinary —although we meet analogous results sometimes in tile, china-biscuit, and other ovens. It shows how careful we must be in assuming that, because ware is fired in the same saggar, it has necessarily been fired to the same temperature. At first sight, I may be wrong, I doubt if anything really reliable as to crazing and porosity can be deduced from Mr. Heath's observations. With variations in composition and variations in firing temperature, the effects due to porosity *per se* are obscured. To examine the effect of porosity on crazing it is necessary to have the composition of body and the firing temperature constant. There are many little things we notice in everyday potting which confirm the

observation that, for ordinary earthenware bodies, the greater the porosity the greater the tendency to crazing, *e.g.*, slip at 30 ozs. is more liable to produce crazing than slip at 32 ozs. There are plenty of examples in tile making, and even where you have composition constant, glaze constant, firing constant and method of making constant, the weight of slip that goes into the filter press has some influence.

I merely mention these points in order to start the discussion, and in doing so I would again emphasise how much we appreciate the tremendous amount of work that Mr. Heath has done. I am sure that, when we have time to consider at our leisure the charts which he has put before us, we shall learn a good deal from the results.

MR. HEATH:—Dr. Mellor raises the point as to the analysis of a ball clay. I may tell you that the ball clay I used was Pike's washed ball clay which was analysed in this laboratory; so that I cannot see that there is anything exceptional about the analysis, and I take it that it is correct. On that matter I have nothing further to say.

On the question of trials being made in felspar and then turning them into terms of stone, I resolved the felspar into terms of bases alumina and silica, but I resolved the stone into these also. I assumed in each case that the bases alumina and silica will act in the same way, whether introduced from stone or felspar, providing there is the same proportion. I think that some remarks that Dr. Mellor once made would tend to bear me out on this point. He once gave us a paper in which he said that a pottery body was really governed by the chemistry of partially completed reactions, and in a good many of the temperatures used I think we might take it that the felspar or the Cornish stone have not had an opportunity of doing their full work. In resolving the felspar into terms of silica, alumina and bases I am assuming—and the American Society had a big discussion on this point—that the bases would act the same, never mind in what way they are introudced. The whole point of the paper however hinges on whether the theory propounded of 70 per cent. silica in a body renders you practically free from crazing. If there is 70 per cent. silica it cannot all be introduced from one source. It has got to come in from other materials besides the flint.

We will take the case of Cornish stone. If we are introducing silica from Cornish stone and the bases are not going to act as bases they are going to take up some of the silica and upset the 70 per cent. theory. So that I reckon I am quite as safe in taking stone as silica, bases and alumina as I should be in taking felspar.

As to the bung of plates in which I got a big difference in the porosity, I may say that that bung was not made up of any of the compositions I have given you. I do not know the composition of the body at all. I simply went to a friend of mine in Hanley, and

asked him if he would mind giving me a bung of plates straight out of the oven, and if he would be good enough to mark the position on them so that I should see which was to the fire side and which to the opposite side in the saggar. The plates came out in the order that I have given you. There were 21 plates in the bung and the top plate had a porosity of 16·27. The middle plate—curiously enough—had the least porosity, viz.—14·61. The 20th plate down —the next to the bottom—had the highest porosity, viz.—18·33, and the bottom plate was 17·41. As to the composition of the body, as I have already said, I am entirely at sea. I know nothing whatever about it.

Dr. Mellor has indicated the importance of the question of porosity variation. In this connection work on a body of constant composition would form an interesting research for a keen student. As further emphasis I may quote that *with a certain plate* a decided variation has been encountered. The side away from the fire had a porosity of 17·41% and on the fire-side the porosity was only 15·9%.

However, I state that I have not considered the measure of porosity any indication of liability to crazing. The correlation of porosity and crazing is not the function of this work; from the nature of the discussion it seems essential to make this fact clear.

I am much obliged to Dr. Mellor for his remarks as to the amount of work that I have done on this subject. Although it has taken some time it has been very interesting. I may say that the coal strike gave me an opportunity of doing some of it.

Dr. Mellor:—May I ask Mr. Heath whether washed ball clay was used?

Mr. Heath:—Yes; it was Pike's washed ball clay.

Mr. Worthington:—I would like to add that we all appreciate this colossal paper which Mr. Heath has given us. I should imagine that it has taken as many months to prepare as it has taken minutes to read. We must all be sorry at times like this that our rules forbid us proposing and seconding a vote of thanks to our members.

I have a number of simple questions to put, but they are questions which, nevertheless, I should like answered.

In the first place I would be glad to know whether there were any ground pitchers in the flint that Mr. Heath used in his bodies. If so, willl he be good enough to tell us the percentage, and can he indicate what different action these ground pitchers would have in the body as compared with flint? Secondly, I notice that Mr. Heath gives us the analyses of biscuit ware. Most of the analyses are, however, made in the clay. Can he, therefore, tell us of a simple way of turning from biscuit to clay to find out the percentage of silica, alumina and bases?

Some time ago we had from Mr. Heath a most interesting paper

on the difference between hard and easy calcined flints. I would like to ask him whether he knows anything about the calcining of the flints that were used in these particular trials recorded in the present paper, and whether he has tried the hard and the easy in these particular trials.

Another question is this: I think a good many people test their ware for crazing, but there are various ways of testing. Would Mr. Heath tell us the method he has used and give us his opinion as to which is the best and most reliable method?

Again, can Mr. Heath give us the surface factor of the silica that he has used? And will he tell us which, in his opinion, is the best surface factor to use in connection with silica?

Finally, Mr. Heath speaks of cones 2 and 3. Would he be good enough to tell us what heat this is in degrees centigrade? Because a good many manufacturers at the present moment use Bullers' rings, and it would be very useful to compare his temperatures with those registered by the Bullers' rings.

Mr. Heath:—The analysis of the flint that I used was silica 91·23; alumina 4·5; lime and magnesia 1·38; potash ·41; soda ·83 and the loss on ignition was 1·84. Anyone looking at that analysis would at once assume that there was something in the silica besides flint. I think there is, and I think most probably that the ground flint has in it a certain percentage of pitchers. If we assume for a moment that there is 12½ percentage of pitchers in—I have not calculated out the exact proportion of pitchers that flint usually contains, but I am acquainted with a batch in which the flint is usually round about 12½ per cent. in its content of pitchers—instead of getting 100 per cent. of silica we get only 95. So that if the body recipe called for 35 of flint in the dry state we should be getting only 33. If that body was anywhere near the crazing limit that 2 per cent. deficiency would be quite sufficient to turn the scale. But if previously we had been using a body which was very far from the crazing limit and if, instead of using a flint having a content of 12½ per cent. of pitchers we now turn over to a pure flint, we should tumble to the other extreme and get peeling.

As to the hard and easy calcined flints, I do not know what flints were used beyond the fact that they were laboratory flints. I could not say anything about their calcination. But, as was previously pointed out, if the body is mixed slop and compounded for a specific gravity of 2·4 and you get it 2·3 this means that it is hard calcined: you get 3½ per cent. too much flint content. This would cause peeling if the body is near the critical point. If the body were originally compounded for 2·3 specific gravity and 2·4 was substituted, the body, being near to crazing, would now be over the crazing limit.

As regards the method of testing crazing, I think I would rather leave that to more competent authorities. A method I adopted in these trials was to leave them out on the roof for six

weeks. In one case I had 47 slabs safe when they were put out and only 5 when finished. A good method to employ in the testing of crazing is to subject the ware to a saturated solution of boiling nitre for about 10 or 12 days.

As to the cones. My temperatures were taken with Bullers' rings as well as cones. The temperature varied from about 37 to 49—37 in the easier fired and 49 in the hard fired biscuit. This corresponds with the cones mentioned in the paper.

With regard to the surface factor I have not determined this. Of course, we know that the surface factor has a great bearing upon the result. As to what I consider is the best surface factor, this will depend entirely on the sort of body you want to get. But I should think for an ordinary earthenware dinnerware factory somewhere about 240 would be the right figure. Dr. Mellor will perhaps correct me if I am off the mark.

Mr. Philip Bailey:—I would like to ask Mr. Heath two questions. The first is: Does he consider that the bases introduced with the pitchers in the flint will act in the same way with a completed body as if they were introduced for the first time with the stone? The point is that the bases that are in the pitchers have already been fired once and, therefore, they have completed certain reactions. If you have a high percentage of pitchers in the body I should imagine that the bases in these pitchers would not act in quite the same way as if they were bases introduced in the raw state. The second point is: Mr. Heath does not seem to have mentioned whether in his opinion a short glost fire as compared with a longer glost fire would have any influence on the crazing of any particular body. I have an idea that the longer the glost fire (so long as the glaze comes out bright and clear) the better chance the glaze has of eating into the body, and, therefore, the less risk of crazing. Some manufacturers, for instance, are using tunnel ovens, in connection with which the opinion of some people is that the glaze is not at a high temperature for so long as it is in an ordinary oven, and, therefore, does not get such a soaking. May not this explain why the glazes used in connection with the Dressler and other tunnel ovens are more liable to craze than they are when used with the same body in the ordinary ovens?

Mr. Heath:—With regard to the bases in the pitchers. Dr. Mellor did not think that the bases in the pitchers would act in quite the same way as if they were introduced direct, that is to say, in the form of stone. I asked other people, and they were of the opinion that they would act more violently, so I have taken the mean between the two opinions and assumed that they will act just the same. We know that if we have pitchers in flint the material comes out harder than if you use pure flint, so that the bases must be acting as bases.

As to the point of the longer glost fire, personally I am inclined to think that the longer glost fire would be more likely to give

freedom from crazing. I do not know whether this is a general opinion, but it is certainly my opinion that the further the glaze eats into the body the more freedom we are likely to get from crazing.

Mr. B. J. Moore:—The point that Mr. Bailey has raised with regard to the length of the glost firing is equally as important, in the case of the biscuit firing. There is no doubt that with a fast biscuit firing, even though you apparently reach the temperature that you do normally, the ware will craze more readily. I think that tile manufacturers have experienced that more than the ordinary earthenware manufacturers—particularly in connection with tunnel ovens.

Mr. F. Turner:—I have not had an opportunity of assimilating the figures that Mr. Heath has given us, and, therefore, cannot discuss the paper from that aspect. But the more one thinks of the subject the more one is convinced that other factors than those which Mr. Heath has mentioned arise to upset our conclusions, and one realises that time is necessary to go carefully through the paper. One point, however, has struck me, and I would like to have Mr. Heath's opinion regarding it. In connection with so many mixtures fired together—all naturally of very varying porosities—how did he ensure an even coating of glaze? Because we know quite well that the same body, under apparently the same conditions, will sometimes have a thin coating of glaze and sometimes a thick coating, and the two examples will give absolutely different results. I do not quite see yet how Mr. Heath ensured the whole of his trials at any particular firing stage having just the same thickness of glaze. With regard to Mr. Heath's experience as to the porosity of his plates, I can confirm this. I do not think it is quite such an uncommon experience as some people would imagine to get a big difference in the porosity of plates in the same saggar. I have often seen a great difference in the contraction also. A plate may often vary very considerably owing to the difference in the pressure that is applied by the maker in its formation. Such factors as these may influence the porosity. Can Mr. Heath be quite sure that all his trials were made under standard conditions of moisture and of pressure?

Mr. Heath:—I anticipated that some question similar to Mr. Turner's would be raised. I may say that I dipped specially to allow for the different porosities. I separated the slabs into degrees of porosity at every 5 per cent. and as early as possible I arranged to get about the same percentage of glaze on each. I also took the precaution of wetting the slabs.

Mr. Dunbar Bishop:—Whilst the results of the porosities on that particular bung of plates might not be altogether unexpected, I hope Mr. Heath will follow up the reason why the plates at the bottom of the bung should turn out with the greatest porosity.

One can understand a greater porosity at the top than the middle, for instance, but the other matter looks as though it needs some further explanation.

With regard to the difference in porosity between the fire side and the other side of the same piece of ware in the oven—which difference, from the rough figures I have put down, amounts to as much as 1½ per cent.—that also, I think, needs a little further elucidation as to the exact position in the oven. I think we ought to have some information as to the distance of the bung of plates in question from the mouth of the oven. If it is in the middle of the oven then the distance from the fire side to the mouth will not be very different from the distance of the non-fire-side to the mouth, but the result is all the more striking, than if the bung of plates were put, let us say, in the first ring, just before the bag, where the difference in distances is greater.

I did not gather whether Mr. Heath mentioned the temperature at which the bung of plates was fired. Perhaps he can tell us that. The only point that occurs to me about body No. 40, which was mentioned as being the most likely to give the best results, is that I am afraid the colour of it for best white earthenware would be anything but satisfactory. If it were unstained or only very slightly stained it would be distinctly ugly, and if it were heavily stained I am afraid the colour would come out a dead grey. There would be no warm whiteness about it.

MR. HEATH:—In reply to Mr. Bishop's question as to the colour of the body, I may say that this did not enter into my consideration at all. I simply gave the results as applying to crazing.

MR. C. D. GRIMWADE:—I feel that this discusson emphasises the importance of using a definite test to show us how far our ware is away from crazing. The charts and curves which Mr. Heath has drawn appear to be defined by wether his trials did or did not craze, after several weeks ordinary exposure to weather. But how far from this border-line do we need to work so that our glost ware may remain sound not only in our warehouses but in the shops and, later still, under the strain of domestic usage? This being ascertained, we want a quick test just severe enough to show that this margin of safety is being maintained. A fairly common test is to boil the ware for an hour in strong brine and plunge it suddenly into cold water. Even so, it seems necessary that the best earthenware should be able to withstand the above treatment more than twenty times in succession before it shows any signs of crazing.

MR. HEATH:—In reply to Mr. Grimwade I think we may say that we can see what he wishes to know fairly well from the charts. Each slab has a number and it is a comparatively easy matter to see from the chart how far that number is removed from the crazing or the peeling line. As to the best method of testing crazing, I may say that I did not simply boil the samples up, but I plunged

them occasionally into cold water. I was talking to Mr. Moore this morning on the point as to what he considered the best method of testing crazing. In America, it seems, they adopt a system of warming up the plates in an oven and then plunging them into cold water. Mr. Moore does not consider that method very satisfactory. He is inclined to think that the use of a steam bath and then dropping the plates into cold water is a better method. As to that I cannot express an opinion. My invariable method was to boil up the test pieces in a nitre saturated solution and then drop them into cold water. It seemed to give good results. But each one, I think, follows his own ideas on this point.

Mr. T. Simpson:—As far as the analysis of ordinary bodies goes, what would Mr. Heath consider to be a safe percentage of alumina and silica?

Mr. Heath:—I have given them in the paper. For practical bodies I have put the figures at 71·1 silica, 19·5 alumina and, say, 4 of bases. That gives you a loss on ignition of 5·4 This is only my opinion, of course, and it is based on the particular analyses shown on the chart.

Mr. Simpson:—Would that suit ordinary commercial glazes such as are supplied to-day?

Mr. Heath:—Yes. That is the body that is farthest removed from either crazing or peeling.

Mr. A. G. Richardson:—I quite agree with Dr. Mellor that Mr. Heath is not quite on the right lines in comparing felspar with stone, because we know that during the wartime when it was difficult to get suitable qualities of Cornish stone quite a large number of experiments were made with a view to replacing the ordinary Cornish stone by other felspathic materials. The results at that time were not very satisfactory. Although the analyses were taken and the silica, alumina and alkali contents were considered, the resultant body was still not equal to that made up from the Cornish stone. I know very well that, at the time to which I refer, many people were exercising their minds with a view to getting a body which they were previously able to get by the use of hard Cornish stone, but which they did not seem to be able to get in the absence of that material. I do not know whether any work on the subject has been done since that time or whether anyone has satisfied himself that, by using other felspathic materials in the place of hard Cornish stone, satisfactory results can be obtained. I think that it is scarcely advisable to conclude that although you have got the same alkalies and alumina and silica content, therefore, you are going to get exactly the same results when transferring from the ordinary Cornish stone to felspar or felspathic material. We know the difficulties through which we have all been passing of recent years, because of the difficulty in getting the real hard purple Cornish stone. Personally I should have been better

pleased if Mr. Heath had worked on a Cornish stone basis, taking, say, two types of stone. That would have helped us considerably in our present practical difficulties. The Cornish stone at the present time is not anything like so good as the pre-war Cornish stone, and, therefore, the pre-war recipes are not safe to-day. Of course, I hardly expect that Mr. Heath will be prepared to repeat his work, but I should be inclined to suggest it. I think the paper will be a very valuable one to us when we can consider it leisurely from a perusal of it in the "TRANSACTIONS."

MR. HEATH:—During the American discussion, Binns, I believe, said that alkali in a body has the same effect no matter in what form it happens to be brought in. Purdy retorts that the alkali introduced into glazes has a very different influence according to the different nature of the source. If that is true, how much more so must it be in bodies? I am rather surprised at Purdy making that remark, because there is no doubt that in glazes the alkali is taken into solution, whereas, in bodies, I think there is no doubt that it has not half done its work. Again, Purdy says: "I know you cannot substitute one clay for another without expecting a difference. But you cannot prove that it is the difference in the felspathic material or the chemical composition." Well, if it is not that, what is it? Why should a different clay give us a difference in the result if it is not owing ot the difference in the chemical composition?

MR. F. CARNALL:—I would like to ask if Mr. Heath has taken into consideration the difference between pan ground and cylinder ground milled materials in making his crazing tests? The laboratory test for crazing is to heat up in an oven to 200 degrees for a quarter of an hour and then plunge into cold water. Is Mr. Heath's test as severe as this, and has he tested two pieces, one, say, by his method and one by the other method and noted any difference in the results?

MR. HEATH:—I do not know whether the materials were pan or cylinder ground. As to the testing of crazing by the hot air method, I have tried this, and I find that an ordinary body, put in at the same time, crazed at 190, whereas the safest body did not craze until it reached a point between 270 and 300 degrees. This was the only test that I made. I have not tested any pieces by the steam bath.

MR. WOOD:—I think Mr. Heath has answered your questions extremely well. The questions have covered a good deal of ground and if Mr. Heath will only agree to go through the whole of his tests again using Cornish stone instead of felspar, I think he will give you all satisfaction. A great amount of work has been done by Mr. Heath, and I think when we get the paper in the "TRANSACTIONS" and digest it, we shall find indications that will put us on the right track. We cannot expect Mr. Heath to give us a standard cure for

every works; he cannot do more than give us some useful points. Those who have listened to him to-night will have received hints that ought to put them on the right way towards minimising crazing. Many hints have, in fact, been given which I am afraid many people have not previously considered in dealing with the question of crazing. There is no doubt whatever that the work which Mr. Heath has done, although it might not perhaps be exactly on the lines that some of us would have chosen, will be of extreme usefulness. As a Society we are very much indebted to Mr. Heath for the trouble he has taken and for the able lecture that he has given us.

XVI.—On the Stresses in Cylindrical and Spherical Bodies due to Differences of Temperature inside and out.

By Charles H. Lees, D.Sc., F.R.S.

IT has been shewn recently that when a body of cylindrical or spherical shape is either hotter or colder at its surface than it is within, the stresses set up by the difference of temperature may be determined by a simple graphical method,* which does not assume that the expansion of the material with rise of temperature is constant.

In Ceramics it is seldom that the bodies dealt with are either simple spheres, circular cylinders or circulars discs, and the calculation of the stresses in the cases of bodies of complicated shapes is still too difficult a problem to be solved completely, but as the sphere, cylinder and disc constitute portions of many of the bodies which occur in practice, we may make our calculations for those portions as if they constituted the whole, if we remember that the interaction of contiguous portions will modify our results in the regions in which one shape passes into another.

1. In order to illustrate the methods developed in the papers quoted we propose to apply them to the following problem :—

A hollow cylinder of circular section (fig. 1), originally at air

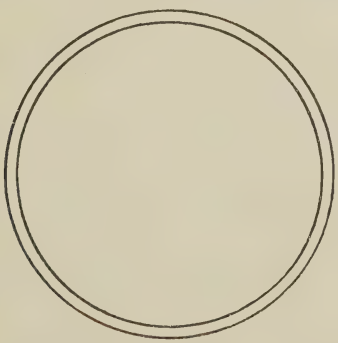


Fig. 1. Section of Cylinder.

temperature throughout, is heated till its outside surface is at 1,000°C. and its inside at 700°C. To find the stresses in the material,

* C. H. Lees. *Proc. Roy. Soc.*, **A, 100,** 379 and **A, 101,** 411, 1922.

its expansion and its elastic constants being given. We shall take the cylinder as being long enough to make the influence of the ends of it on its middle portion slight. A slice of the cylinder bounded by two planes perpendicular to the axis and near the middle of the length in the unheated state, remains a slice bounded by planes perpendicular to the axis in the heated state, but the planes are not at the initial distance apart.

Let the connection between the rise of temperature and the volume dilatation of the material of the cylinder be given by the

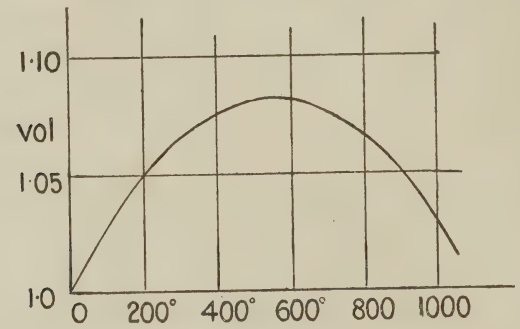


Fig. 2. Dilatation of material.

curve fig. 2 and let the distribution of temperature throughout the section of the cylinder be given by the curve θ (fig. 3), where the abscissae represent the area of section and the ordinates excess of temperature over the original temperature.

Construct the dilatation curve D for the elements of the material

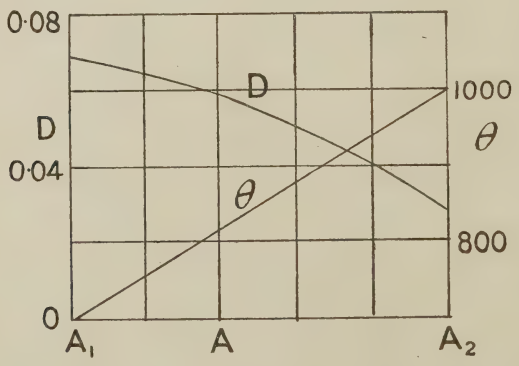


Fig 3. θ the temperature, D dilatation throughout the Section A_1A_2

between the inner and outer surfaces A_1A_2 by erecting ordinates at a sufficient number of points in fig. 3 to represent at each point

the dilatation of 1 c.c. of the material due to the rise of temperature at that point above the initial temperature. Join the points so obtained to get the dilatation curve D.

2. From the dilatation curve determine the increase of volume of each of the thin concentric cylindrical shells 1 cm. high into which the shell itself may be supposed to be divided, the increase of volume of each thin shell being considered as independent of and uninfluenced by the change in its two immediate neighbours. It is in securing a proper fit between consecutive shells which have expanded differently that thermal stresses may be supposed to originate. This increase of volume may be found by dividing the base of the dilatation curve fig. 3 into a convenient number, say 10 or 20, of equal parts each of which represents a volume $\frac{1}{10}$th or $\frac{1}{20}$th of that of a centimetre length of the original cylinder. If we multiply each of these elementary volumes by the dilatation per unit volume it experiences, as shewn by the ordinate of the dilatation curve D, we get the increase of volume of each element. Each product is represented by the area enclosed between the element of base line taken, the perpendiculars drawn from its ends and the length these perpendiculars cut off from the dilatation curve D. The total increase of volume of the material enclosed between the inner surface of the cylinder and a concentric surface through the point A is therefore represented by the area enclosed between the base A_1A the perpendiculars through A_1 and A and the portion of the dilatation curve they enclose. The increase of volume or expansion curve E (fig. 4) is thus drawn, and its final ordinate A_2E_2 represents the total increase of volume of 1 cm. length of the given cylinder. If the cylinder had been heated to a uniform

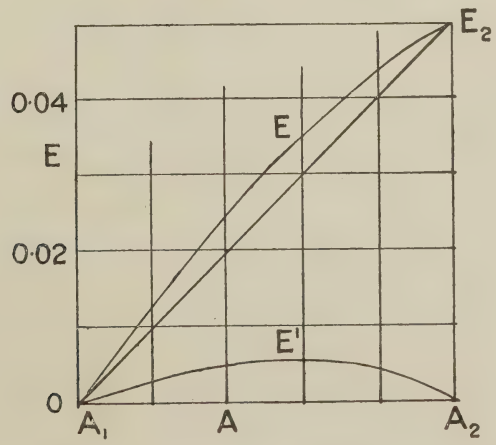


Fig 4. The actual (E) the mean and excess (E^1) expansion up to any section. The numerical values to be multiplied by $A_2—A_1$

temperature throughout, the expansion curve would have been the straight line joining A_1 to the end E_2 of the expansion curve above A_2 and we may call this straight line the mean expansion curve. But a uniform expansion throughout the cylinder would produce no stresses. Hence we require only the excess of the expansion at each point over the mean expansion; that is, we require only the excess of the ordinate of the expansion curve E over that of the mean expansion curve at any point. It is convenient to draw this excess expansion curve E_1 on a larger scale as in fig. 5.

3. It is also convenient to record the stress which an elementary portion of the shell exerts on its neighbouring portions in terms of the components of stress R along radial lines, T along lines tangential to the circular section in planes perpendicular to the axis of the cylinder, and X along lines paralled to the axis of the cylinder. It is further convenient to reckon these components as positive when pressures and negative when tensions.

Let P (fig. 5) be a point on the excess expansion curve and

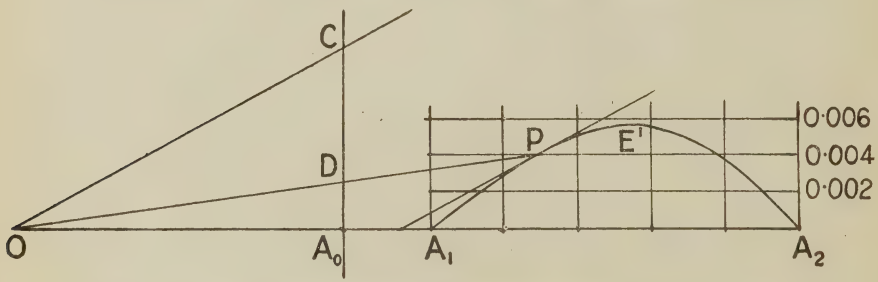


Fig. 5. The excess expansion curve E^1 and P a point on it. OP and OC give intercepts A_0D and A_0C which determine the stresses; OA_1 and OA_2 are not to the scale of fig. 1.

O the centre of the cylinder. Join O to P. Through P draw a tangent to the curve and through O draw OC parallel to the tangent. At some point A_0 representing a volume of cylinder 1 cm. long, which is a convenient multiple of 10, erect a perpendicular and let it cut the line OP in D and OC in C.

Then if $\approx$ is Young's modulus and σ Poisson's ratio for the material of the cylinder, the components of the stresses at the point represented by P are given by the following equations:—

$$R = \tfrac{1}{6}\frac{\varepsilon}{1-\sigma}\frac{A_0D}{OA_0}$$

$$T = \tfrac{1}{6}\frac{\varepsilon}{1-\sigma}\frac{2A_0C-A_0D}{OA_0}$$

$$X = \tfrac{1}{6}\frac{\varepsilon}{1-\sigma}\frac{2A_0C}{OA_0}$$

By taking P at a number of points on the curve of excess expansion the values of the components at these points are determined and the three stress curves R, T, and X (fig. 6) are drawn to shew how the components of stress vary throughout the material

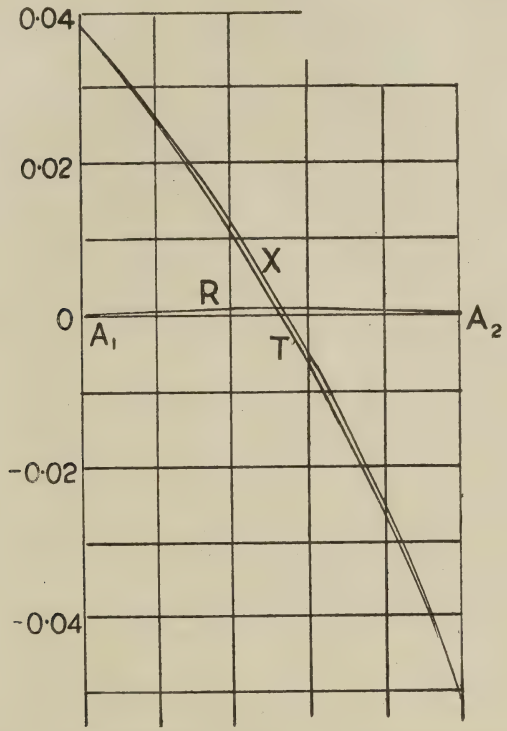


Fig 6. The stresses RT and X throughout the section.

The numerical values to be multiplied by $\frac{1}{6}\frac{\varepsilon}{1-\sigma}$

of the cylinder. It will be noticed that $X=T+R$ at each point

4. The ordinates of Fig. 6 shew the coefficients of $\frac{1}{6}\frac{\varepsilon}{1-\sigma}$ in the values of RT and X throughout the material of a cylinder which expands on heating according to the curve of fig. 1, which has the area of its outer section 1.1 times that of its inner, the outer surface being raised to 1,000°C. and the inner to 700°C., from the initial temperature of 20°C., and the temperature in the material itself at the instant considered being taken as a linear function of the area of the section through the point. It will be noticed that the radial pressure R is small throughout in comparison with the tangential T and the axial X. This is due to the smallness of the ratio of thickness of material to diameter of the cylinder and R

would approach T and X in value as that ratio got larger. So long as the cylinder is hollow the radial pressure is zero at both inner and outer surfaces. The tangential pressure T and the axial pressure X have their largest numerical values at the surfaces. Both R and T are pressures and equal in amount at the inner surface, and both tensions, again equal, at the outside surface.

5. Since for most of the materials used in Ceramics the breaking strength under tension is less than that under pressure, it is in the values of the tensions that we are most interested, for if they exceed the tensile strength a crack forms. It is seen from the expressions for stresses given in §3 that we require to know Young's modulus and Poisson's ratio of lateral contraction to longitudinal extension for a stretched rod of the material before we can assign numerical values to the stresses. The value of the latter ratio is probably 1/3 even at high temperatures for most of the materials with which we are concerned, but we know little at present as to the value of Young's modulus for these materials or their tensile strengths at high temperatures. This is a direction in which research is urgently needed.

For a solid cylinder the determination of the stresses is made in exactly the same way as for a hollow cylinder. The staring point A_1 of the excess expansion curve is now at the centre O, and the quotient A_0D/OA_0 when the point P on the curve approaches O becomes identical with A_0C/OA_0

6. For a thin disc of circular shape, either having an opening in the centre or being continuous to the centre, the graphical work is identical with that for the corresponding cylinder, but the stresses are then to be calculated from the following formulæ :—

$$R = \tfrac{1}{6}\,\varepsilon\,\frac{A_0D}{OA_0}$$

$$T = \tfrac{1}{6}\,\varepsilon\,\frac{2A_0C-A_0D}{OA_0}$$

the stress perpendicular to the flat surfaces of the disc being zero if the disc is thin, and the radial and tangential stresses having only about 2/3 the values they would have for a long cylinder of the same shape as the disc and with the same distribution of temperature.

7. For a spherical shell the graphical construction is carried out on a base line OA_1A_2 as before, but distances from O are taken proportional to the *volumes* of the spheres drawn through the points considered, instead of being proportional to areas of sections. The stresses are then calculated from the following formulæ :—

$$R = \tfrac{1}{9}\,\frac{\varepsilon}{1-\sigma}\,\frac{2A_0D}{OA_0}$$

$$T = \tfrac{1}{9}\,\frac{\varepsilon}{1-\sigma}\,\frac{3A_0C-A_0D}{OA_0}$$

8. If in any case the change from the initial temperature is such as to involve a decrease of volume, the dilatation, expansion and excess expansion curves are below the axis of section or volume, but the graphical construction is carried out as before, and one or more of the points C, D of fig. 6 lie below the horizontal through O.

In all the cases considered the stresses in the material were due to the rise or fall of the temperature of the material from some uniform to some non-uniform distribution, and the values given are for the stresses which exist in the non-uniform condition. Those cases in which material, whose contraction on cooling differs from its dilatation on heating, passes from an initial low uniform temperature through a high non-uniform temperature state to a low temperature again uniform, are reserved for a further communication.

XVII.—Notes on the Application of Pyrometers to Ceramic Industries.

By C. E. Foster.

THE general description of the different types of pyrometers, with historical notes (more or less accurate), has been indulged in by various speakers *"ad nauseam"* and I believe that most learned societies have been the victims of that kind of dissertation. I therefore wish to steer clear of that method of treating the subject of pyrometry, and to devote my remarks more particularly to some of the detail problems which arise in applying known types of pyrometers to various branches of the Ceramic industries. I shall assume, in order to save time, that the general nature of the different types of electrical pyrometer now in use, optical, radiation, thermo-electric and electric resistance, are well known, and their principles of operation are broadly understood. But, if the general nature of these instruments is well understood, it is a fact that the detail application of them to various industrial processes has not been studied so much as it should be in order to achieve the best industrial result.

This has been due to sins of omission and commission on both sides, both the instrument maker and the user have been guilty. The instrument maker, on his side, has frequently claimed too much for his instrument and, in an effort to simplify his manufactures, he has been tempted to offer an instrument of any given type as more or less suitable for universal application. On the other hand the user, particularly when that user possesses the little knowledge which is held to be a dangerous thing, has been inclined to demand a pyrometer which shall be regarded as universal in order to simplify his own problems of applying the instrument to his work.

If such an ideal of universal application could be achieved without sacrifice it would certainly be worth while, but it is a fact that very large sacrifices must be incurred in any attempt to use an instrument for a wide range of applications without alteration of the details. To take a simple instance of a thermo-electric couple, it is well known that the wires of which the couple is composed must be mounted, insulated and protected by some suitable form of sheath. If the instrument is intended for portable work with frequent insertion in different positions for short periods, the type of sheath selected would not be suitable for long continued insertion in one position.

In very many branches of manufacture progress has been made possible by specialization of the apparatus to the particular process. Progress in pyrometry is proceeding and, I think, should proceed along the same lines. While endeavouring to avoid the

rather profitless general description, the considerations of actual application and installation of pyrometers cannot well be undertaken without taking into account some points in their principle and construction. These general principles have been arrived at as the result of years of experience in connection with many different industries, nearly everyone engaged technically in the pyrometer industry having contributed valuable details. I shall not attempt the difficult task of apportioning credit, partly because I believe technical progress is often due to the reaction of the ideas of one man on the mind of another; one is often quite unaware of the actual source of an idea which later becomes embodied in what is called an invention. I might also mention one name and omit another equally important, thus unintentionally drawing an invidious distinction. Happily the pyrometer industry is one remarkable for the friendly relations existing amongst those engaged in it, and I am sure it will be agreed that such relations lead to the advantage of technical progress.

Many of the arrangements that I am about to describe are embodied in instruments of my own design and, therefore, to that extent, my arguments may be regarded as an "*ex parte*" statement, but I may perhaps point out that, in selecting my main points of design, there was little in the way of patents or other matters preventing me from copying existing designs, or from re-producing designs I had previously made for other people, and there would be every commercial reason for following accepted practice; therefore, where I have broken away from traditional methods or arrangements it is because the technical advantages seemed to me in favour of the change.

In considering the application of a pyrometer to industrial work, the matter of the electrical resistance of the circuit is almost of fundamental importance. To take, as an example, the thermo-electric pyrometer as being possibly the most widely applied electrical instrument in the Ceramic industry, the diagram in Fig. 1 illustrates successive developments of the thermo-electric circuit.

"A" shows the simplest form of the circuit, but of course, it is not a practical arrangement for actual measurement; it is necessary to interpose an indicator as shown at "B." In this case it will be seen that the so called "cold junction" becomes really two junctions but usually close to each other and at the same temperature. If the indicator itself is at the same temperature as the two cold junctions, then it is immaterial what metals enter into the indicator circuit, the measurement will depend simply on the temperature difference between the hot junction and the cold junction.

As is well known, it is necessary that the resistance of the circuit should remain approximately constant with changes in temperature in any part of the circuit, in order that, for any given temperature of the "hot junction," the current flowing in the

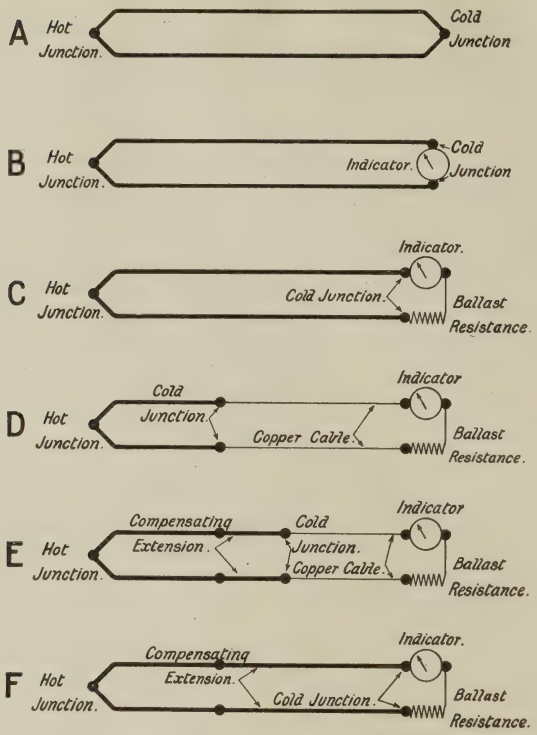


Fig. 1.

circuit (and consequently the reading of the indicator) shall be approximately the same as when the instrument was calibrated. As the moving coil in the indicator is usually of copper, there will be an appreciable change in resistance with change in its temperature; it is, therefore, necessary to interpose also in the circuit a "ballast" or "swamp" resistance, of material which does not change appreciably with change in temperature, and so large that the change in the resistance of the copper portion of the circuit shall be negligible within the limits of accuracy desired in the particular class of measurement. This arrangement is shown at "C." If, for any reason, it is not convenient to prolong the thermo-couple itself to the indicator position, then there is interposed a length of copper cable as shown at "D." This copper cable will change its resistance with change in temperature and will require to be taken into account when the amount of "ballast" resistance is determined.

It is here important to note that the essential condition in this matter requires that a large proportion of the total instrument resistance shall be of material which does not change appreciably

with change in temperature. It is not essential, from this point of view, that the total resistance should be high, but only that the *proportion* of ballast resistance should be high. As is well known, the current flowing in any electric circuit will depend upon the electrical resistance of that circuit; the lower the resistance the greater the current. It is also assumed as understood that the instrument called an indicator is an arrangement with a moving coil, carrying the current to be measured, turning in the field of a permanent magnet. The forces tending to turn that coil in the field will be greater when the resistance of the circuit is low and the current, therefore, large. This matter reacts directly, and in a very important degree, upon the robustness of the apparatus.

In addition to the copper in the circuit one other consideration affects the question of circuit resistance, namely, the resistance of the thermo-couple itself and its change of resistance when it is heated to different temperatures and different depths of insertion in the furnace. If the conditions require the use of a "rare metal" couple of platinum and its alloys, it is evident that, owing to high cost, the wires must be very thin and their electrical resistance will be relatively high. Further, it happens, unfortunately, that these metals increase their resistance very largely when they are heated in a furnace, so that, in the case of rare metal couples the ballast has to be increased considerably to "swamp" this effect.

In those cases, however, where the conditions allow the use of "base metals", the materials being relatively cheap, the cross section of the thermo-couple may be large, and its electrical resistance correspondingly small. Further, there are base metal alloys which can be used successfully, in which the increase of resistance, when heated in the furnace, is also very small. To make such a base metal pyrometer of low total resistance and yet capable of accurate measurement, it is, therefore, only necessary that the proportion of ballast resistance shall be large enough, and there is no essential need for a high total resistance.

A numerical example of such a low-resistance circuit may help to elucidate this point.

		Ohms.
(1).	Resistance of 3 ft. thermo-couple, when cold	0·10
(2).	Probable variation of thermo-couple resistance due to different depths of insertion and into furnaces at different temperatures	0·01
(3).	Resistance of copper cable at normal temperatures	0·25
(4).	Resistance of copper coil in indicator at normal temperatures	2·00
(5).	Probable change in resistance of cable (3) and coil (4) due to change in atmospheric temperature	0·09

		Ohms.
(6).	Therefore probable maximum change in circuit resistance, sum of (2) and (5)	0·10
(7).	Added "ballast" or "swamp" resistance ..	7·65
(8).	Total resistance, sums of (1), (3), (4) and (7) Probable change in resistance, the proportion of (6) to (8), is therefore 1 per cent. and, on this count, the accuracy should remain constant within this limit.	10·00

It will be seen that the figure allowed for cable resistance is 0·25 ohm, which may be considered rather low but, with such a cable resistance, the smallest section of cable advisable, from considerations of mechanical strength, will allow a distance of 30 ft. between, which is quite convenient for a pyrometer made up and used as a unit. Where, in different circumstances, longer cables are desirable, they can be made up to 100 ft. long without undue increase in size or cost. Indeed, it may be fairly argued that a small saving in cost of cable is dearly bought if it involves the use of a more delicate instrument exposed to rough industrial conditions. As to this matter of robustness, it is easy to show how and why the low resistance indicator is inherently more robust than one of high resistance.

Taking, as a rough approximation, that a low-resistance circuit will be about 10 ohms, while a high resistance for base metal will be about 100 ohms, it will be evident that, for the E.M.F. developed by any thermo-couple at any particular temperature, the current flowing in the low-resistance circuit will be 10 times that in the case of the high resistance. In order to make the two instruments strictly comparable the moving system (coil, pointer, etc.) in each case should be of the same total weight. The coil in the low resistance circuit will, therefore, consist of fewer turns of thicker wire. In actual practice the number of turns would be reduced in the proportion 1 : 2·5. The force tending to turn the coil in the magnetic field, against the resistance of the control spring, is proportional to the current flowing multiplied by the number of turns in the coil (ampere-turns), so that the forces in the low-resistance circuit will be about $\frac{10}{2{\cdot}5} = 4$ times as great as those in the high-resistance instrument. In actual practice it is found that it is 5 times or even more. The control or torque for full scale deflection is usually expressed in dyne-cms., typical figures in the case of high and low resistance indicators being 16 and 80 dyne-cms respectively.

Now, it is indisputable that, methods of construction and conditions of use being the same, the chance of survival in accurate condition is proportional to the forces controlling the moving system; thus a low-resistance circuit has a better chance in proportion of say four or five to one. That, briefly, is the argument

for low-resistance, always provided the circuit resistances are properly proportioned on the lines indicated, and where the pyrometer can be used as a "unit" under known and fixed conditions.

In those cases where much longer cables are unavoidable, it is usually possible that the position chosen for the indicator can be well protected, so that the relatively delicate high-resistance instrument can be used safely. Similarly it has already been made clear that, in cases of rare-metal couples, a high-resistance circuit is essential. A numerical example of such a rare-metal pyrometer is given below. It should here be noted that the remarks relating to indicating instruments, in whcih a pointer moves over a scale, apply with equal force to recorders, in which a pen or other similar device marks on a chart.

		Ohms.
(1).	Resistance of 3 ft. thermo-couple when cold..	2
(2).	Probable variation of thermo-couple resistance due to different depths of insertion and into furnaces at different temperatures	1
(3).	Resistance of copper cable at normal temperature	1
(4).	Resistance of copper coil in indicator at normal temperature	24
(5).	Probable change in resistance of cable (3) and coil (4) due to change in atmospheric temperature	1
(6).	Therefore probable maximum change in circuit resistance, sum of (2) and (5) ..	2
(7).	Added "ballast" or "swamp" resistance ..	173
(8).	Total resistance, sum of (1), (3), (4) and (7).. Probable change in resistance, the proportion of (6) to (8), is therefore 1 per cent, which is quite satisfactory industrial accuracy.	200

Now, from the points of view of the maker and the user, there is an added embarrassment, when using rare-metal thermo-couples, namely, the relatively low E.M.F. developed by such couples. To take the E.M.F. developed at 1,000°C., with the cold junction at 20°C., a good type of base metal thermo-couple will give 40 millivolts, while the rare metal, at the same temperature, will only give 10 millivolts. Thus we see that, contrasting the base metal low resistance, with the rare metal high-resistance the current flowing will be as $\frac{40}{10} : \frac{10}{200}$, 80 times as great. Actual practice would show that the forces are about ten times as great.

This is not to be taken as an argument against using rare metal thermo-couples where they are otherwise desirable, but rather

for the need of special care in installing and using such instruments, or of some special design tending to make high-resistance instruments relatively robust. The remarks above will have shown that the forces available to move the coil of the indicator in its magnetic field are in any case very small, and particularly so in the case of high-resistance instruments as required for rare metal couples. It is little to be wondered at that the earlier instruments were made with moving coil suspended by a very fine metallic strip, whose torsional resistance provided the necessarily light control. But such a suspended coil requires that the instrument be very accurately levelled in order that it may swing clear, and also that it be placed on a very firm support free from vibration. It also made necessary some device for locking the coil and taking its weight off the suspension when the instrument was to be moved about. Probably many here will have vivid recollections of troubles in using such instruments under industrial conditions.

These troubles naturally turned the attention of both makers and users to the question of using a coil carried on pivots with very fine points, carried in conical jewels, but the problem was not easy to solve.

A torque of 10 dyne-cms. is, of course, the turning effort of a force of 10 dynes working on a radius of 1 cm. A mental picture may be formed by imagining the axis of the movement horizontal, having attached to it a pulley 1 cm. radius, round which a light thread is wound; on the end of this thread would be suspended a weight of 1/100 gramme, or 10 milligrammes.

This is indeed small, but it must be remembered that this is the force for a deflection from zero to the full extent of the scale. Now, consider what is the force available to move the pointer, against static friction, when the temperature under measurement changes by a very small amount. Consider an instrument scale from 0° to 1,100°C., and suppose that the temperature rises from 900° to 905°C. The deflecting force of the current due to 900°C. will be $10 \times \frac{900}{1100} = 8{\cdot}2$ dyne-cms.; but, when the temperature was at 900°, this force was actually balanced against the control spring because the movement is supposed at rest in equilibrium. Now, when the temperature rises by 5°, the unbalanced force due to this rise has to start the pointer moving against static friction, yet it is only $10 \times \frac{5}{1100} = 0{\cdot}045$ dyne cms., or, in the case of our imaginary pulley, a weight less than one twentieth of a milligramme on the end of the thread. Nevertheless, a user would not consider favourably an instrument that was "sticky" to a greater extent than 5°, even after considerable use.

Obviously it became necessary, if a pivotted instrument of high resistance was to be successful, to make the whole moving

system very light and to mount it on pivots having extremely fine points. This makes a fairly satisfactory instrument when it is first assembled, but vibration or rough usage very soon resulted in a "sticky" instrument, in which friction errors due to damaged pivots or strained moving system caused objectionable errors. It is clear that if, without excessive cost or complication, the whole moving system can be sprung so that it is practically impossible for the pivot to strike a blow on the jewel, the instrument may be expected to survive rough usage which would otherwise be dangerous. The spring mounting known as the "Resilia" seems to offer a satisfactory solution of this difficulty. Fig. 2 shows this

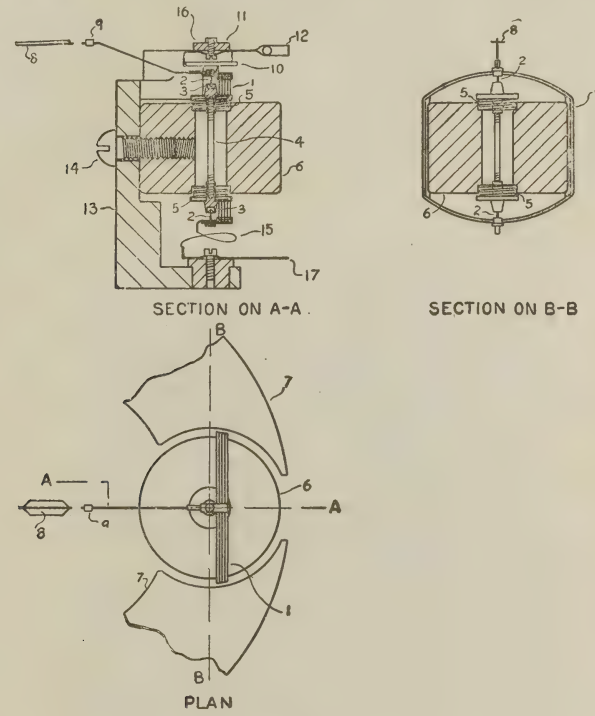


Fig. 2.

construction. A magnetic field is established between the pole pieces of the magnet 7 and the cylindrical iron core 6. The coil 1, carrying the current by means of which the measurement is made, swings in the space between 6 and 7, turning about an axis 4. The coil carries inturned pivots 2, having their bearings in the concial jewels 3. These jewels are mounted upon a staff 4, which itself is very light and which is held in position relatively to the core 6 by the light spring 5. Any jolt of the instrument, therefore,

will move the whole system of coil, pivots, jewel and staff, and it is impossible for the pivots to strike a blow on the jewels. The current to be measured is led into the coil through the control spring 10, and the ligament 15; thereafter the circuit is carried by the frame 11 at the top and by the insulated arm 17 at the bottom. The zero is controlled by the arm 12. Attached rigidly to the coil is a light pointer 8. The coil 1 is mounted slightly eccentric to the axis 4 so that its weight balances the weight of the pointer 8, a final adjustment of balance being made by the position of the small sliding weight 9. This construction avoids the necessity of a counterweight tail and counterweight, usually previously employed and, therefore, enables the weight of the whole moving system to be kept to a minimum; thus the controlling forces may be small and the pivot points very fine, and, therefore, the internal resistance of the instrument can be high without introducing objectionable mechanical delicacy or friction errors. The core 6 is held by the screw 14 to the rigid frame 13, which, in turn, is attached to the magnet and combines the whole moving system into a unit. With

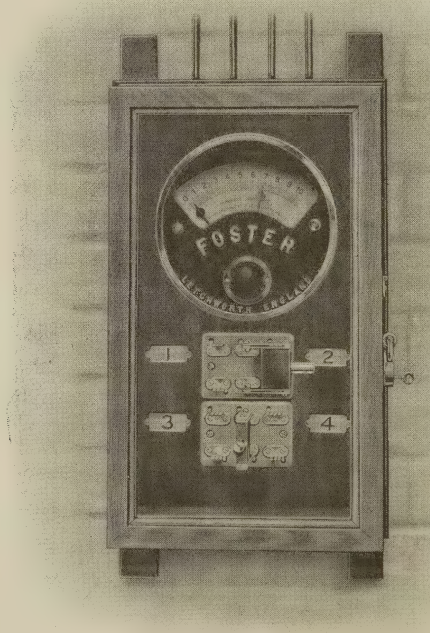


Fig. 3.

this construction the ordinary vibrations in industrial use do not result in broken pivots or "sticky" action.

As already explained, in a pivotted instrument the control against which the coil turns when a current flows through it is provided by spiral control springs, which also serve to lead the current into and out of the coil. When first calibrated, the whole moving system is put in accurate balance, so that without the control of the springs it would remain more or less indifferently at any position of deflection. There is no gravity control at all and the only forces on the coil are due to the springs. With the low resistance type, and its relatively large controlling forces, any minute changes in the perfection of the balance are negligible, and therefore, the instrument may be made to work with a flat vertical scale, like a switchboard ammeter, the axis of the movement being horizontal. Although the effects of pivot friction are greater in this position than with the axis vertical, the forces are sufficiently large to overcome such friction, so that advantage can be taken of the undoubted convenience of this kind of instrument, as seen in Fig. 3.

But in the case of a high-resistance instrument the forces are so small that the axis of the movement must be approximately vertical, this posture giving the smallest pivot friction, and also being least affected by any small change in the perfection of balance. For this reason all high-resistance instruments should have the axis of the movement vertical. To make a convenient wall type instrument of this kind the pointer is bent downwards and moves in front of a curved scale known as the "edgewise" pattern. An example of this type is shown in Fig. 4.

These matters may be summarised by saying that there is no special virtue in high resistance in an instrument, where the pyrometer can be treated as a unit; with a base metal couple, it may, legitimately, be of low resistance, with great increase in robustness, but where the use of rare metal couples or other considerations demand a high resistance, it should be kept as low as is consistent with the required accuracy. It should be designed to withstand, as far as possible, industrial conditions and then used with full knowledge of the very small forces controlling its moving system.

The foregoing remarks indicate that the choice between rare metals and base metals is largely fundamental in its effect on the matter of robustness of the whole instrument; it is, therefore, worthy of some study before proceeding to the consideration of actual installation. The term "base metal," designating the relatively cheap metals as distinct from the "rare" or "noble" metals of the platinum group, is perhaps an unfortunate one ; in the past, coupled with the mistakes made in choice of metals and methods of use, it has led to the impression that the qualification "base" might also be applied to the performance of the instrument, the treatment it deserved and the technical standing of those who made it. With

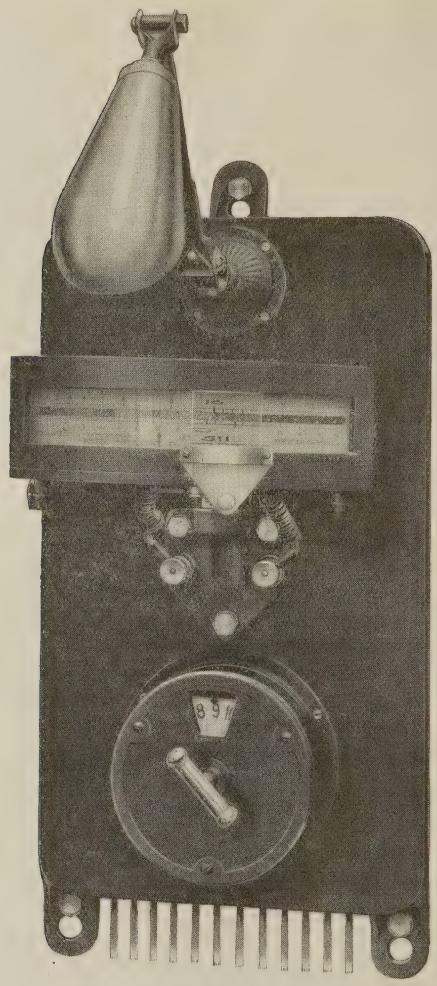


Fig. 4.

alloys of the nickel-chromium series, as developed originally in America, continuous work may be done at temperatures as high as 1,200°C., while, for short tests, measurements may be carried up to 1,300°C., or even higher, provided care is taken in certain simple details, which, it is worthy of remark, involve usually much less trouble than similar precautions in the case of rare metals. When actual industrial installations are examined, as distinct from laboratory and research work, it is surprising how few cases there are where rare metal couples are in continuous use at temperatures

over 1,200°C. The fact that the rare metals are still well below their melting point at 1,600°C. is, in itself, little comfort to the user, when he finds it difficult to discover a sheath which will protect the wires for any length of time from deleterious furnace gases at 1,300°C.

Considering the thermo-couple with its sheath as a whole, the difficulty resides in the fact that heat is being applied to produce some desired change in the material under manufacture, yet it is also desired that the same heat shall not produce any change in the part of the pyrometer exposed to that heat. While this is an ideal which can be closely approached at low temperatures it becomes much more difficult as the temperature gets higher. It is readily recognised that the brick lining of a kiln will require renewal at intervals, yet this brick lining is subject to attack only on one face; but the pyrometer sheath, of much smaller bulk and thickness, is subject to attack all round. The problem is, therefore, more difficult and renewal is likely to be more frequent. If the breakage takes place in the furnace and it is not discovered at once, the expense of renewal will involve not only the new sheath, but probably also the replacement of the thermo-couple wires.

The functions of a sheath are two-fold. In the first place, at high temperatures, the mechanical strength of the thermo-couple wires will be very low; to some extent they will be in a condition known to metal workers as "hot short" and, therefore, need some form of support to prevent sagging in use. Secondly, furnace gases are known to attack all metals in varying degrees, producing oxidation, contamination and coarse crystalline structure, all of which conditions are inimical to the life and accuracy of the thermo-couple. In the case of rare metals, oxidation may be neglected, but contamination may be so serious that it is essential to use a sheath which, at the working temperature, is not permeable to gases. Fused silica is quite useful up to 1,100°C., and has the great advantage that it does not crack with rapid or unequal heating or cooling. But it is very fragile, and, under prolonged heating at or over 1,100°C. it tends to devitrify and then, even if it does not fall to pieces, it ceases to be gas tight.

A high quality of porcelain stands up better to exposure at high temperatures, and, if glazed externally, will be gas tight up to 1,300°C. or even higher. But, unfortunately, it is liable to crack if it is heated or cooled rapidly or unequally. It is somewhat stronger mechanically than silica, but is, nevertheless, more fragile than one would wish for a part of an industrial instrument. To get over the difficulty of cracking due to unequal heating, the porcelain sheath is frequently encased in an outer fireclay tube, sometimes with asbestos wrapping round the porcelain, to act as a cushion in handling. Although this arrangement is largely used, it is more or less a case of making the best of a bad job. If the Ceramic Industry can supply the pyrometer maker with a sheath

that is as gas-tight as porcelain, as indifferent to rapid heating as quartz and as strong as a good fireclay, the sheath problem will be solved, and the pyrometer maker, with present day knowledge, can, in return, give the Ceramic industry an instrument that will be almost trouble free.

But, pending the arrival of this pyrometric millenium, it is necessary, by careful consideration, to make the best adaptation possible with available materials.

With base metals the requirements as to sheathing are in many ways less onerous. Although the wires will be hot short at high temperatures, even to a greater extent than with rare metals, they are of much larger cross section and, therefore, on the whole, of greater mechanical strength. Furnace gases do attack base-metal wires, particularly if those gases are heavily laden with carbon monoxide or sulphur fumes, but in view of the relatively low cost of replacement, it is actually cheaper to use a simple fireclay sheath that is fairly strong and cheap, even if not entirly gas tight. Oxidation of the wires, when in a sheath, proceeds so slowly that it is almost negligible. If the life of the couple is only limited by oxidation the upkeep cost will be very small. It has even been found advantageous to construct the sheath so that there is a slight admission of air, in order to oxidise and render innocuous any furnace gases which may penetrate the sheath.

To summarise this section, it may be said that all thermo-couples require care in the choice and use of a sheath at high temperatures, but that, in view of the cheaper and less onerous conditions as to sheathing in the case of base-metal couples, the replacements of the sheath will be cheaper, while the renewals of the thermo-couple, if more frequent than in the case of rare metals (this is by no means certain) will be so much lower in cost that the total upkeep is often found to be very much less. Thus the cases where it is necessary to use rare metals in industrial work are only relatively few.

Turning now to details of installation the first point for study is the location of the thermo-couple in the furnace. Consideration of kilns of any of the usual types for bulk production shows that they are all heated by passage of products of combustion through the actual working space or "laboratory" of the kiln. In the early stages of firing a kiln of the ordinary type it is clear that the products of combustion will be at a very much higher temperature than the walls of the kiln or the material in it; but even after the kiln has reached a steady temperature there will still be some excess in gas temperature, because the work in the kiln is radiating outwards to the walls, which are themselves losing heat by conduction and radiation at their outer faces. Compared with the bulk of the work and the kiln walls, the mass of the thermo-couple in its sheath is very small, and if it is inserted deeply into the path of the gases it will experience and indicate a temperature that is con-

siderably hotter than that of the walls and it may also easily be in excess of that of the work. This may lead to a false idea of the actual temperatures of the work and, in any case, it tends to shorten the life and increase the upkeep cost of the pyrometer.

In this connection it must be borne in mind that the transfer of heat from the gases to the walls etc., takes place primarily by convection; conduction through the mass of the gas is probably relatively small, and, of course, radiation from gases is very slight compared with that from solids. But, once the surfaces of any solid have been heated by the gases, then heat will be transferred fron the hotter to the cooler surfaces in the kiln by radiation, and it is well known, that heat radiation rises very rapidly with increase in temperature; for instance, the heat radiated from any surface at 1,200°C., will be roughly sixteen times as great as from a surface at 500°C. This fact will explain how very unequal the temperature distribution may be at relatively low temperatures, and it also opens the way towards a solution of the pyrometer problem. If the thermo-couple is arranged so that it is not directly in the path of the flames but is well exposed to radiation from the material in the furnace, it will then avoid unduly high readings in the early stages of the firing and will show, with good accuracy, the final temperature of the work.

Obviously, this suggestion condemns as unsuitable the common expedient of inserting the thermo-couple through the crown of the kiln; but it is also arguable that this position is not the best from another point of view. It is well known that the temperature at the top of any heated space is usually higher than that at the bottom, so that the passing of a given minimum reading with a thermo-couple in the crown is no assurance that the ware at the bottom has been fired to that degree. If there is no fixed limit to the number of thermo-couples to be used on one kiln, obviously it would be very nice to have a large number, some high up and others low down, but, usually, this is not practicable. It is, therefore, suggested that a better position is fairly low down and, if possible, the tip of the sheath should be in a pocket or recess. This will protect it from breakage, and at the same time it will be out of the direct path of the gases, but will receive radiation from the material under treatment. This method has also the advantage that it allows a relatively short thermo-couple and sheath, with reduction in the first cost and also in the frequency and cost of replacements. To anyone used to the old method of insertion, the readings in the early stages will appear disappointingly low, but it is suggested that this will be due to the old method having given erroneously high readings.

Another problem which often arises is the application of very long thermo-couples, where it is desired to measure the temperature at a point near the centre of the kiln. Where a great length has to be exposed to high temperatures, this is one of the most troublesome operations with any inserted type of pyrometer, because

all the sheath complications are multiplied roughly proportionally to the increase in length. If such a deep insertion is essential for continuous work, very careful study should be made to get the best conditions. Insertion vertically will avoid trouble due to sagging, but will probably involve exposing part of the sheath to very high temperatures; on the other hand, insertion horizontally will lead to trouble unless the sheath can be supported along its length. It is suggested that very often the troubles due to deep insertion of long sheaths may be avoided by installing a short thermo-couple and sheath in a convenient position and then only using the long thermo-couple for occasional tests to establish the relation between the temperatures in the two positions. It will then only usually be necessary to use the long thermo-couple when any change is made in the method of firing or in the class and arrangement of the ware in the furnace. With the relatively shallow insertion it is, of course, important to see that, when a renewal is fitted, it is inserted to approximately the same depth.

The next point to consider is the arrangement and location of the "cold junction." The current flowing in the circuit, and, therefore, the pyrometer reading, depends on the difference in temperature between the hot junction in the kiln and the cold junction somewhere outside. It is, therefore, essential for routine operations that the cold junction shall be placed where it will be at a fairly steady temperature, and where it will be at about the same temperature at the same stage of firing, in successive firings. Referring to the diagram, Fig. 1, the arrangements D, E and F are the only ones that need be considered. D shows the cold junction actually at the head of the thermo-couple. In this position it will certainly not be very cold, owing to conduction from the internal heat, but this is not, in itself, any particular disadvantage, but the same conduction will cause very considerable change during the firing so that it is not a desirable arrangement; although it was at one time a common method it is now rightly discarded.

The arrangement in E is now very frequently adopted. A length of conductor is attached to the head, the wires being thermo-electrically interchangeable with those in the thermo-couple; this is generally called "compensating extension" or "compensating cable". Thus the actual cold junction may be removed from the effect of direct conduction and usually a relatively short length of a few feet will transfer the cold junction to a place where it is sufficiently steady in temperature for industrial work. Where the thermo-couple is inserted through the crown, it is usually necessary to have a larger compensating extension than where the insertion is low down through the side, and, when considering a low-resistance outfit, this is a point of some importance; an extension greater than 20 feet would introduce an undesirable additional resistance. In the simplest cases, where the kiln is under cover, it suffices to arrange the cold junction so that it experiences just the general atmospheric

temperature a few feet away from the kiln, but, where the kiln is out of doors or it is desired to have greater accuracy, the cold junction may be buried in the ground, or enclosed in a thermos flask, or arranged in an oil bath in which is inserted a small mercury thermometer so that the actual temperature can be read from time to time. Where the accuracy desired, or other conditions, require a longer extension than 20 feet, it is usually worth while to consider the alternative high-resistance circuit. In that case the compensating extension may be prolonged to the indicator itself, as shown at F, thus securing good cold junction conditions.

To take account of the cold junction temperature, it used to be the common method to set the pointer of the indicator to zero on the scale, when disconnected from the thermo-couple, but, since in industrial work it was not usual to find the actual cold junction temperature at freezing point, a correction had to be applied to each reading. The current flowing in the circuit was proportional to the excess of E.M.F. due to the hot junction above that due to the cold junction, the latter acting as a "back E.M.F." It was, therefore, necessary to add to the reading an amount in degrees corresponding to the E.M.F. at the cold junction. Very few thermo-couples have what is known as a "straight line law" of calibration; the E.M.F. for the interval 0°–30°C. would not be the same as from 1,000°–1,030°C., so that, if the actual cold junction temperature were 30° and the uncorrected reading 1,000°, it would not be accurate simply to add the 30°. The amount to be added would vary according to the actual temperature of the hot junction.

Since, however, the scale of the indicator will be marked off in accordance with the calibration law of the actual thermo-couple, the addition may be made in another way. If, before the reading is taken, the pointer is set opposite the actual cold junction temperature, then, when connected up, the reading observed will have the true correction added without calculation. A further step in simplification is to do this operation automatically and continuously. If the compensating extension is continued right up to the indicator, then it is possible, by means of a bimetallic spiral or other similar device, to move the zero setting of the pointer automatically with change in the instrument temperature.

Reference is perhaps desirable here to a device which was produced in America, which is put forward as an automatic cold junction compensation, but which is based on a technical fallacy; it has not been largely adopted in this country, but it seems important to explain the fallacy on which it is based. Adjacent to the cold junction a chamber is placed, rather like an enlarged mercury thermometer, so arranged that, as the column of mercury rises with increase in the cold junction temperature, it short circuits or cuts out an increasing length of resistance wire which dips into the mercury in the form of a loop. This really amounts to applying a factor to compensate for a term in the equation. An arithmetical

example will make this clear. Suppose that the hot junction of the thermo-couple is at 500° while the cold junction is at 15°, and that the instrument is then in correct adjustment. Now let the cold junction temperature rise to 25°. Without any correction or compensation, the reading would fall, and, supposing for the moment that the thermo-couple has a straight line law, this would cause a fall in reading to 490°, a drop of 2 per cent. at this reading. The device described would be arranged so that, for this 10° rise in cold junction temperature, it reduced the circuit resistance by 2 per cent.; thus there would be an increase of the same percentage in the current flowing, and the reading would be restored to 500°. But suppose now, that the reading were 1,000° instead of 500° and that the same rise took place in the cold junction temperature; apart from the alleged compensating device the reading would fall to 990°; the compensating device, reducing the resistance by the same 2 per cent. would cause an increase of this percentage in this reading so that it would now be 1,010°, that is, the error would be as large as if no compensating device had been there, but of the opposite sign. In short, such a device can only operate correctly for one particular reading.

The placing and protection of the connecting cable, or compensating extension, running from the thermo-couple position to the indicator or recorder is worthy of more study than is usually given to it; more care should be taken than in the case of a circuit for light or power, not, as sometimes happens, the sort of wiring that would be suitable for an electric bell. The continuity of the conductors should be good, all contacts should be firmly made, preferably with soldered joints wherever possible, small pin plugs and things like little lighting switches should be avoided because they will sooner or later introduce a serious variable resistance. The voltage on a lighting circuit is usually enough to break down a skin of oxide or other corrosion when the two parts of the circuit are brought together, whereas, with something between one tenth and one hundredth of a volt, the slightest film of oxide will cause trouble. If a poor contact on a lighting circuit should cause a reduction of 5 per cent. in the current, the lamp is rather dull, but nothing very serious happens, yet a reduction of this percentage in a pyrometer circuit would cause a very large drop in the reading; for instance, with a true temperature of 1,200° the reading would be only 1,140°. It is, therefore, clear that the points where the circuit is broken should be as few as possible, contact surfaces should be fairly large, as self-cleaning as possible, but also readily accessible for periodical cleaning.

Wherever there is any chance of exposure to weather or rough usage, the cable itself should be fixed in strong conduit and the cable should be strong and well protected, so that no harm will be done in drawing it into conduit. Money spent on such items is a good investment, for all parts of a pyrometer circuit are equally important,

a fault on the cable is just as serious as a damaged indicator.

The position chosen for the indicator or recorder is very important, and involves considerations of psychology. The furnace man is, in any case, liable to regard the pyrometer as a nuisance; if it is put away out of his sight in a superintendent's office he will regard it as a spy, and there is no pyrometer made that cannot be deranged by anyone who is hostile to it. It is, therefore, suggested that the instrument should be put where the furnace man can see it. This is usually done in modern installations, and it is found that the attitude of the men is soon altered, and the instrument comes to be regarded as a friend rather than an enemy. The old days when the superintendent had an instrument in his office and then went storming out to the furnace man when the temperature did not appear to be correct, are rapidly passing away; it is nowadays realized as necessary to enlist the goodwill of the man actually doing the firing.

Another modern tendency in the right direction is the use of a recorder in place of an indicator. In a modern recorder the record can be read at any time as easily as an indicator, the slope of the line tells the furnace man not only where the temperature is at the moment, but also where it is going, so that he can regulate his firing in the most intelligent way, and, of course, there is the advantage of a permanent record for reference afterwards. The objections to be urged against a recorder are its greater cost and complication, but the advantages are so great as to be well worth while if a simple and robust instrument is chosen. The recorder can easily be housed near the kiln, protected by a house with a glass front, so that the record can be seen, although the instrument cannot be interfered with by any unauthorized person.

As already pointed out, the considerations of circuit resistance and robustness apply to recorders with equal force as to indicators, but there are also considerations of the automatic mechanism to drive the chart and make the record thereon. Perhaps the first point to be considered is the method of making the record on the chart. The consideration of the forces acting to move the pointer or pen will make it evident at once that, if the pen rests all the time in contact with the chart, the forces will not be enough to move it across the chart when the temperature changes, the friction errors will be hopelessly large. It is, therefore, necessary to adopt one of two alternatives:

(*a*). The pen or other marking agent remains normally out of contact with the chart and is, therefore, free to take up its proper deflection with no more liability to friction error than the indicator; it is then made momentarily to mark on the chart.

(*b*). The mechanism may be indirect, embodying some kind of mechanical or electrical relay whereby the variations of the deflection are made to move a pen across a chart, the pen not being in direct connection with the moving coil system.

Broadly speaking, it may be said that if simplicity is to be the governing factor the former type (*a*) will be chosen, whereas, if a somewhat greater complication is accepted there are advantages in the latter (*b*) arrangement; it is possible to use a wider chart with more open scale than can be accommodated easily in the intermittent type (*a*).

In the case of the intermittent record (*a*) it should be understood that, in ordinary work, the separate markings all join up into a practically continuous line. The marks may be made by the application of liquid ink to the front surface of the chart, or may be produced by the interposition of an impregnated surface such as a typewriter ribbon ; in the latter the mark is sometimes made on the under side of a semi-transparent chart in order to avoid the covering of the most recent part of the record by the ribbon. In this latter arrangement, the chart is inevitably rather delicate for industrial use.

The form of the chart comes next for consideration. It may be in rectangular form, mounted on a drum, rotating, for instance, once in 25 hours, in which case, it is usually necessary to remove the drum from the recorder to see some of the record; but this drum type has the advantages of a chart of fairly convenient size and the paper may be fairly stout and strong; it can also be arranged with rectangular co-ordinates, the various division lines all being straight.

Another type is the continuous strip chart in which paper is drawn from a roll in a continuous strip and the record may be allowed to run on for several days without attention. Some users object to this type because it is found that it is allowed to run on without attention and, therefore, the full use of the record is not always obtained. But this strip chart has the same advantage that it may have rectangular co-ordinates, and also the whole record may be visible without disturbing the instrument. Usually, the chart has to be rather thinner than seems desirable for industrial work.

Lastly, the chart may be a disc. This type is considered a rather inferior arrangement academically, because it cannot be made with rectangular co-ordinates, usually all the division lines are curved. If it were of any industrial value to integrate a temperature chart, the fact that this disc chart would require an integrator of special construction might be allowed as a disadvantage, but, practically, integration on a temperature chart would have no meaning; 10 hours at 500° would give the same arithmetical product as 5 hours at 1,000°, but no one would contend that it would give the same ceramic product. This disc chart has certain practical advantages that make it well worth consideration for industrial work. As the chart never need be bent at all, it can be made of very stout paper; the whole of the record is visible at any moment without disturbing the recorder and, when removed at the end of the run, it is in convenient form for handling and filing. Since the usual record desired is a steady rise to a certain maximum, the

holding at that maximum for a period and then the slow cooling, it is as easy to follow and govern this on a disc chart as on any other. Fig. 5 shows an example of the disc recorder.

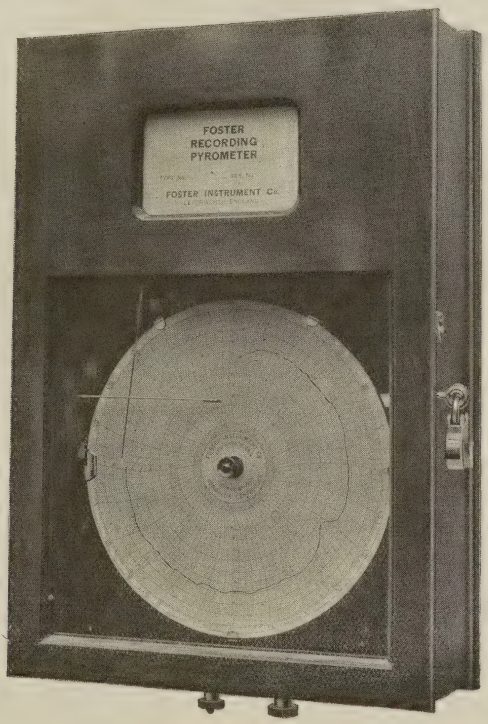


Fig. 5.

In connection with recorders on kilns I should like here to refer to a suggestion made many years ago which appealed to me at the time, but which has not, so far as I know, been as widely adopted as it deserved. Before the chart was put in the recorder, two lines are drawn showing the limits within which the firing should be kept and a bonus would be paid to the firemen for every hour he kept the temperature between the two lines. This scheme would at once remove the recorder from the category of spy to that of friend, the fireman will take an interest in his work, and, further, he will be eager to report any failure of the pyrometer, so that it will not go neglected for any undue length of time. Perhaps, when this suggestion was made, industrial conditions were not favourable to any extra payment, but I suggest that modern tendencies may now lead to a reconsideration of this bonus arrangement.

It is surely better to pay a man extra for doing well than to reprimand him for doing ill.

Clockwork is the usual device employed for running the recorder mechanism, and, in a well designed recorder, there should be a large margin of power to allow the instrument to continue running under adverse conditions. Some development has taken place with electrical drive in place of clockwork, particularly in large installations, where very many recorders are grouped together, but if simplicity is desired and decentralization adopted, the independent clock-driven recorder is probably the better arrangement.

A recorder may be fitted with an alarm arrangement so that a bell is rung or a lamp is lit whenever the temperature passes above or below certain limits, which can be set by the user; in some industries this system has been extended also to automatic control, but it does not appear that this latter extension could be usefully applied to kiln firing at its present stage of development. The alarm system is, however, a very useful adjunct for calling attention of the firemen or foreman.

Another device which may be applied to a recorder is an automatic commutator, by means of which the instrument is connected in turn to each of several thermo-couples, the record lines being arranged, by different colours or systems of dots and dashes, to be distinguishable. This automatic commutator is attractive because it reduces the first cost, but it should only be adopted where careful consideration shows it to be suitable. To put two or more records, say, from different kilns on one chart is not advisable, because probably the records should be at or about the same temperature, and they will, therefore, be rather confused. The extra complication of the commutator, with its additional load on the driving mechanism and consequently greater possibility of trouble, will hardly be justified. But where there are two temperatures, both of which are to be recorded practically continuously, and where they are industrially related, it is justifiable then to consider the automatic commutator; for instance, in the case of a thermo-couple low down and another high up in the same kiln. There will, probably, always be a difference between the two temperatures; they will not be liable to confusion, and the difference between them will have a definite industrial meaning.

The matter of contact resistance in the circuit has already been considered and, in that connection, it should be borne in mind that the forces available to operate the automatic commutator are likely to be much smaller than those in the case of a hand-operated switch, so that the detail construction of the automatic commutator is worth careful consideration. But again, it is worth while investigating other ways of achieving equivalent records. One way is to have a single case enclosing two separate moving coil systems, each marking on a separate part of one large chart, the whole "double recorder" being driven by a single mechanism.

This can only be done with the drum or the strip type of recorder, and the reduction in cost is not very great, it is only due to the saving on the clock and the case. Another way, not so attractive technically, but actually resulting in good work, is to interpose a hand operated switch in the circuit between two thermo-couples and a single recorder. The recorder is then switched over periodically by the fireman from one to the other, for instance, every hour; this ensures that he does actually pay attention to the record once each hour.

The foregoing remarks have been devoted to the thermo-couple type, but much of the matter in connection with indicators, recorders and circuit details also applies to the resistance thermometer, and the "total radiation" pyrometer which are next to be considered.

The resistance thermometer, operating by the change in resistance of a coil of fine wire which is put in the place of the "hot junction" of the thermo-couple, requires an outside source of current; it does not produce its own E.M.F. It depends upon the balancing of the varying resistance of this coil of wire, known as the "bulb," against other resistances in the instrument. Since this point of balance may be made to correspond with any particular temperature, it follows that the scale may start from any particular temperature, and thus a very open scale can be secured. But, in addition to the complication of the necessary battery, there is the fact that, under industrial conditions at high temperatures, the wire in the "bulb" may suffer distortion with consequent increase in resistance and an *apparent* rise in temperature. Contrasting this type with the thermo-couple, if distortion should take place in the latter type, affecting its heated junction, and increasing that by, say 1 per cent., this would only represent a very small fractional increase in the resistance of the whole circuit and the result on the reading would be negligible; but, in the case of the resistance thermometer bulb, which actually employs finer and more delicate wire than the thermo-couple, an increase of 1 per cent. in the resistance of the bulb would result in an increase in the temperature reading of the same percentage. It seems, therefore, fair to say, that the resistance thermometer should not be used industrially at temperatures where distortion is likely to occur, and, therefore, that it is not a type of much interest to the Ceramic industry.

Considerable progress has been made in the application of radiation pyrometers to high temperature measurement. In the case of a pyrometer which operates by the total range of heat radiations, both short visible and long invisible wave lengths, known as a "total radiation" instrument, the heat radiated from the hot body under measurement is concentrated upon some device sensitive to heat, for instance, a very small thermo-couple. The instrument then operates in the same manner as an inserted thermo-couple. The E.M.F. available is usually more than that of a rare-

metal thermo-couple and less than that of a base-metal thermo-couple at the same temperature to be measured.

There is no particular difficulty about circuit resistance; it may, quite legitimately, be of low resistance for the following reasons. In the first place, the resistance of the little thermo-couple is relatively low, and it does not change much with its temperature. Secondly, owing to the law of a total radiation pyrometer being a "fourth power" law, it follows that a relatively large change in the current flowing makes only a small change in the temperature reading; for instance, the circuit resistance may alter by as much as 4 per cent. without introducing an error in the reading greater than 1 per cent.

This type of instrument has obvious advantages in the measurement of very high temperatures, because no part of it is subjected to the actual high temperature measured. But it is also obvious that, if the measurement is to be made direct, it involves an opening into the kiln through which the radiation may pass out to the instrument. Very often such a condition cannot be tolerated for anything except short exploring measurements, and it is then necessary to resort to an indirect method. A tube of refractory material, closed at one end, is inserted into the kiln, and the inner surface of this closed end then radiates to the pyrometer. Thus we again have to face the trouble of a refractory tube inserted into the kiln so that the same kind of difficulties arise as in the case of the thermo-couple sheath, modified by the fact that the tube usually is necessarily larger, and, therefore, stronger, and, in the event of its failure, the sensitive part of the apparatus need not be damaged.

While it is necessary to accept this method of the closed end tube it requires consideration in installing, if accurate results are to be achieved. The tube is usually necessarily of relatively large diameter, 3″ to 6″, in order to provide a sufficiently large hot surface for the pyrometer, so that cooling by convection currents is considerable. If the tube is inserted with its closed end lower than its open end convection will be greatest, while, in the reverse posture, it will be reduced to a minimum.

To avoid these difficulties with the closed end tube, and yet not to have an admission of air into the kiln, experiments have been tried with windows of transparent material. Glass has, unfortunately, the property of absorbing a very great part of the long heat waves, so much so that a thickness of about 2 millimetres absorbs about 50 per cent. of the heat energy of the radiation, and owing to the "fourth power" law this would require a 25 per cent. addition to the observed reading. Quartz or clear mica do not absorb quite so much, but still the effect is objectionable and will involve special calibration for each material and thickness. Even if this is got over, there is always the difficulty that, when the window gets dusty and dirty, as it must very quickly in this position

in the wall of the kiln, the absorption rapidly increases.

Therefore, this solution of the problem is usually only justified for short periods in experimental work. It should here be noted that the application of such a window to the radiation pyrometer itself is not subject to the dust problem to so great a degree, but, of course, that does not stop the ingress of cold air to the kiln. When a closed-end tube is employed, it is valuable to use also a portable radiation pyrometer to explore, by means of another opening, the temperature distribution in the kiln and thus to establish the relation between that distribution and the reading with the closed-end tube.

In the application of a radiation pyrometer it is important to know the distinction between the focussing and the fixed focus type. In the former a focussed image of the hot body is projected on the thermo-couple junction and the adjustment varies with each size of hot body and working distance, but a focussing instrument has an easy method of verifying that the focus is correct. Such a pyrometer has a working distance of about 20 times the diameter of the hot body and, at the common distance used, a cone of vision which tapers towards the hot body, as shown at "A" in Fig. 6, because its mirror or lens is usually fairly large, say 3 inches in diameter. On the other hand, in the fixed focus type the actual image projected on the thermo-couple is that of the front aperture of the instrument tube; it therefore has a cone of vision which expands towards the hot body, from a relatively small aperture, as shown at "C" in Fig. 6. Such an instrument usually has a smaller working distance, for instance 10 times the diameter of the hot

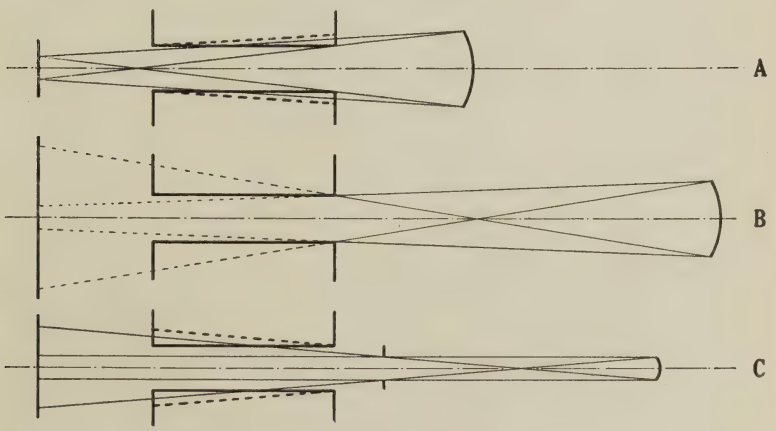


Fig. 6.

body. Fig. 6 shows that, with a relatively small peephole, errors may arise unless the hole is suitably enlarged at one end. In the case of the focussing type, in the view "A" it will be seen that the

hot body cannot radiate fully to the mirror; some of the radiation is cut off by the edges of the outer end of the peephole, the image, as seen by the eye would be complete but the instrument would read low because of the part of the radiation cut off. If, on the other hand the pyrometer were focussed on the front of the peephole, as shown at "B," instead of on the hot body itself, a similar low reading would result because part of the radiation received would then be from the relatively cool sides of the peephole. With such an instrument, therefore, the peephole should be coned out on the outer face. On the other hand, it will be seen that the fixed focus, as shown at "C," needs the hole coned out on the inner face, and since the working distance is shorter, it will probably require more coning out. Against this is the advantage that if the field is clear as seen in the sighting device, it will then be certain that the instrument is properly pointed and will read correctly.

It is worthy to note that, as optical pyrometers are also of the focussing type, these considerations also apply to that type, although the trouble is less likely to arise, as the lenses are usually of relatively small diameter. It is, however, a point worth noting when dealing with very small openings. An optical pyrometer is, strictly speaking, one in which the visible brightness of the hot body is measured or extinguished. In the extinction type, the hot body is viewed through an absorbing medium, the thickness of which is increased until the observer considers that he can no longer see the hot body. Obviously, such an instrument requires to be used with the full knowledge that the sensibility of the eye depends enormously on the length of time it has been in the dark, it is fair to say there will be a large personal element in the measurement. The other type depends upon the matching of the brightness of the hot body against that of a source of light carried with the instrument. Here the personal element is much less, exposure of the eye to a bright light will only decrease the closeness of the match and will not alter the position on the temperature scale. One division of the matching type is known as the disappearing filament type, in which an incandescent lamp filament is seen superposed on the image of the hot body, the current through the filament being varied till it disappears against the hot body, the actual temperature reading being made by the current flowing through the filament. This type requires, of course, a source of current, an accumulator for extended work or a so called dry battery for a few short tests, but it can be made into a convenient portable instrument.

One great advantage of the optical pyrometer is that it can be used at much greater working distances, and on much smaller hot bodies, than the total radiation type. Against this is the undeniable need of rather more skill on the part of the user, an experiment must be performed before a reading is obtained. The optical pyrometer cannot, or course, be made to give an automatic record.

Since what is measured is the brightness of a surface, it is obvious that reflected light may have an important effect on the reading, it is possible to get quite a high reading when the pyrometer is directed on a cold surface that is brilliantly illuminated, for instance, a piece of red paper in a strong light, luminous flames throwing their light on the surface under measurement, or intervening between it and the pyrometer, may cause large errors. Non-luminous flames will not, however, have much effect. In distinction, flames, even when luminous, have not a very noticeable effect on the reading of a "total radiation" instrument, even when the flames are luminous enough to obscure the solid body behind them, the actual reading made will be very closely the true surface temperature of the hot body where there are only a foot or so of thickness of those flames. Where the path of the radiation is through very many feet of flames it will have an effect on the reading, raising it slightly where the flames are at a temperature very much in excess of that of the hot body, but if the flames are at about the same temperature as the body behind them they will radiate approximately as much energy as they absorb.

Some brief consideration should be given to what are known as "black body" conditions. A "black body" in this connection is not one that necessarily looks black, in fact, it is one that, for any high temperature, will look less black than any other body at the same temperature. The term means a body which is devoid of all reflecting power and would therefore, look black when not hot enough to emit visible radiations. A "black body" is realised in actual kiln work by a small opening into a uniformly heated enclosure. Both calculation and experiment show that, even when there are considerable variations in different parts of a kiln, if they are viewed through a relatively small opening, the measurements made will be very closely true temperature readings. Where the "black body" conditions do not obtain the reading will be lower than the true temperature by a larger amount with the total radiation type than with the optical instrument but in both cases the correction may be too large to be ignored unless purely comparative readings are in view for any single process and set of conditions.

It is not practicable, in the scope of a single paper, to discuss all the types of pyrometer that are or can be applied to some section of the Ceramic Industry, necessarily the consideration has been given to those which are most widely used ; the Seger Cone and other articles of that kind are very useful adjuncts to any process in which the firing of ceramic ware is involved, because the cones themselves are of the same nature and effects of atmosphere, exposure to flames and duration of heating will affect them in somewhat the same manner as the ware. Such devices should, I think, be regarded as adjuncts to, rather than substitutes for other pyrometers ; they cannot give any continuous indication of the tempera-

ture variations if their condition is to be inspected during the firing, it involves an opening into the kiln, and then a portable radiation or optical pyrometer can give more information as to temperature, distribution, it is obviously impracticable to distribute series of cones in as many places as can be seen from an opening. Probably a set of cones in the centre of the ware will be found to give valuable information as to temperature relation between the maximum attained on the pyrometer record and the actual maximum reached at the centre of the kiln, but, of course, such information is only useful for future guidance, it cannot be used while the firing is going on.

In conclusion, I would urge careful study of the nature of each type of pyrometer used or contemplated for use, so that its capabilities and limitations are fully understood. It is only by such means that the best results can be attained and technical progress maintained. No pyrometer realizes the ideal, and probably none ever will. As technical improvements are made they will probably be accompanied with a demand for a higher standard of progress and the ideal specification for a pyrometer will be correspondingly advanced.

XVIII.—Note Books of Josiah Wedgwood.

By B. Moore and Dr. J. W. Mellor.

SO many eulogies have been written on Josiah Wedgwood, and so many brochures and books have been written about him and his works, that one would be inclined to say off-hand that the subject has been exhausted ; and that nothing new can now be brought forward. Before the war, however, while clearing up for some extensions, Messrs. Josiah Wedgwood & Sons found a number of notebooks in Josiah Wedgwood's handwriting. An allusion to these notebooks was made by one of us in the appendix to "The Personal Life of Josiah Wedgwood the Potter" (London : Macmillan & Co.), and one of us said :

> "To-day it is difficult to realise the state of chemistry at the time when Josiah Wedgwood flourished. There was no Dalton's atomic theory ; the systematic investigation of gases had barely commenced ; coal gas was not in use ; the combustion of coal in pottery ovens was said to be due to the escape of phlogiston from the coal, rather than to the union of the coal with the oxygen of the air ; and chemistry itself was autocratically dominated by the old king Phlogiston. In Paris, Lavoisier's invincible balance and merciless experiments were heralding the coming of a successor ; in England, Priestley was fighting valiantly for the doomed monach. The influence of Lavoisier's victorious revolution upon the subsequent development of chemistry has been so great that several modern writers exaggerate the effect, and state that the science of chemistry was itself inaugurated by Lavoisier. In any case, the orthodox chemistry of Wedgwood's day was pre-Lavoisierian, and his chemistry must be judged accordingly."

It is equally difficult to realise the state of potting. Apparently, in Wedgwood's time, the mixture of clay and flint was not sifted after mixing, but was merely stirred together and then put on the slip kiln. There were no filter presses available, and the blunging was done entirely by hand. There were no pug mills, and consequently, wedging and slapping had to take its place. We admire particularly Wedgwood's observation under difficult conditions. The very fact that he was working under these adverse circumstances made it so much more necessary that he should observe actual facts, and it is largely owing to this that he made the progress he did.

One of the notebooks contained what appears to be a small pamphlet on the managing of manufacturing pottery, and, with the permission of Mr. Frank Wedgwood, we have the privilege of bringing this work before the notice of our Society. We propose to make copious quotations from this manuscript, together with some comments of our own. We shall be able to show that several ideas, which we consider to be modern, were worked out carefully and faithfully 150 years ago; we shall also be able to show that some modern ideas, which are regarded as of no value by many manu-

facturers of to-day, were considered to be of the greatest importance by this remarkable man.

Two photographs from pages of his manuscript are here reproduced.

Josiah Wedgwood starts by stressing the necessity for care and cleanliness in the preparation of the body. He said:

> "Preparing the clay is the first business in order of time, and ought to have very particular attention paid to it, as the beauty and value of the manufacture must, in a great measure, depend upon the mixing and preparing of the body. If this is done in a careless and slovenly manner, whatever the materials and composition be, the manufacture made from them will be coarse, disgusting and of little value. (The person who looks after this part of the business must begin his attention with the arrival of the raw materials, the kiln, cisterns, etc., being supposed to be properly prepared for their reception. He must weigh the clay, and lay it up into the store room for that purpose, with as much cleanness as if it was intended for food.")

Wedgwood could not well have emphasized the importance of this in a more apt manner. The ball clay, in those days, was received in balls, about 80 balls per tally or ton. He is very suspicious of ball clay and subjects it to close scrutiny.

> "When the ball clay is dried, a careful person must first clean every ball and single piece with proper knives and scrapers. This business must be done upon a bench of planks fixed before a good light. Let the man have a basin of water and a sponge, and wipe every part of the ball with it where he suspects any dirt, which will be discovered much clearer by this wet sponge than a dry brush. When he has cleaned his clay perfectly on the outside, it must be removed to another bench, where he must break it with a wooden mall or a hammer, and examine the inside, for red or yellow veins and other foulness are often found there, and greatly discolour the clay: these must be carefully picked out, they being generally a very strong iron earth."

Wedgwood then emphasizes the care which must be paid to the lawns, and he draws attention to the mischief likely to arise from sifters made with two soft a wood, which may result in particles of wood-fibres getting into the lawned slip. He said:

> "Besides the lawns being good of the kind and of proper fineness, and they should be examined every day, that none of them are burst into little holes, or worn too thin in some places, or frilled and become uneven in their threads by either the warp or the woof being got too near together in some parts and too far off in others, any of which faults will spoil all the slip in the tub sifting into, and if, for want of timely examination, the slip goes into the kiln, and from thence into the heating house, the mischief will be very extensive. The nottings should likewise be attended to, that is the coarse part which does not pass through the fine lawn, but is emptied out of it, for if the slip makers are paid by the weight of ball clay put into the blunger, they will be under a temptation of making too much nottings, that is, emptying it out of the lawn each time before it is sifted sufficiently to get all the good clay out. This may be discovered by the thinness of the notting, for if the slip is clean sifted out from them, they will be much thicker than the slip. They should, therefore, have a tub to empty the lawns into, which should be examined two or three times a day, when the overseer comes into the slip-house.

Pottery

Preparing the clay is the first business in order of time, and ought to have very particular attention paid to it, as the beauty & value of the Manufacture will in a great measure depend upon the mixing & preparing the body. If this is done in a careless & slovenly manner, whatever the materials & proportion in composition be, the manufacture made from them will be coarse, disgusting, & of little value [The person who looks after this part of the business must begin his attention with the arrival of the raw materials, Then in order an idea that the pits, cisterns, &c. are being supposed properly prepared for their reception. He must weigh the clay, & lay it up, with as much cleanness as if it was intended for food, & the flints, must be measured & stored in cisterns with covers to them, which should be kept in their places, that is upon the cisterns, at all times except when they are bringing in or taking out the flint. [When the ball clay is dried ~~ready for mixing~~ ~~& putting into water~~ a careful person must first clean every ball and single piece with proper knives & scrapers. This business must be done upon a bench of planks fixed before a good light. Let the man have a bason of water & a sponge† and wipe every part of the ball with it where he suspects any dirt which will be discovered much cleaner by ^ This wet sponge ~~will discover it much cleaner~~ than a dry brush When he has cleaned his clay perfectly on the outside, it must be removed to another bench where he must break it with a wooden mall or a hammer, and examine the inside, for red ~~discolored~~ or yellow veins & other foulnesses, ~~which~~ are often found there & greatly discolour the clay: these must be carefully picked out, they being generally a

† The only objection that occurs to the wet sponge, is that the clay when moistened may take up some of the dirt & wash off from the outside.

of the ware which we find
surface when they come out of the G O, the flint in this case being in an
over proportion to the lead

Let the plates & all the flat ware be set upon stilts when it is dipt;
otherwise, when they are rested one up to another, the bottom of the plate will gener-
ally rob the edge of its glaze in that part where they touch each other.
It likewise gives the dipper a better opportunity of putting a little glaze on
that part where his fingers touches the edge of the plate.

Gloss oven

~~The Sagars~~, as we burn from 8 to 10 G O's every week, the Sagars will require
considerable attendance ~~to be that all things go right here in them~~

We may begin ~~in the Sagars~~ with the ware; they should at all times be kept dry, & none
of them stay long out of the ovens, for if they do, they will acquire a dampness
from the air, which will be pernicious to the ware fired in such Sagars by preventing
more or less the glaze from vitrifying, & principally on the edges & bottoms
of the ware. This is a circumstance I have often proved, & by putting a piece
of a wet brick into a Sagar full of glazed ware, nearly the whole of the
surfaces have been quite dry, & covered with large air bubbles like pustules of the
small pox. Every means therefore shd be used to prevent moisture being
imbibed by the Sagars. If any of them have been kept out of the oven for
some weeks, they should be fired the first time empty. Agreeable to this principle
of moisture when imbibed by the Sagars being injurious when thrown

The slop-weight of the slip is then discussed; and the drying of the blended clays on slip-kilns. Filter-presses had not then come into use. The testing of the clays is described; and Wedgwood then discusses the testing of the ground flint for its degree of fineness. He draws attention to ferruginous impurities which may be present. He continued:

> "To detect these impurities, dip two or three biscuit dishes thickly with glaze on the face side. Sift the powdered flint from a hair-sieve over the glazed dish, and tap the sieve gently with the hand till the glaze is all over dusted with the flint. If the glaze dries too fast for the flint to stick, dip the plate first in water. After burning the dishes in the glost oven, the coloured particles in the flint are sure to shew themselves."

Wedgwood then discussed the effect of lime in the flint.

> "The flint sometimes comes in such a state, that though it is made as thick as it can be used, yet the tin-pan full cannot be made heavy enough. This is owing to burnt lime being mixed with it at the mill, and may happen there without the miller's intending it, for the flint being ground by chert stones, and those being intermixed more or less, (some of them to a very great degree), with limestone, the miller when he has *used* these stones in runners and pavers till they are too small to answer their purpose, the practise with some at least is to burn them up and use them as flint, in which case it appears from some experiments I have made for this purpose, that a pound of burnt limestone will thicken as much water as x pounds of real flint. The millers soon discover this thickening quality of lime, and as they have so much from the manufacturer per peck for grinding the ground flint, they are uuder a sufficiently strong temptation to use even quicklime for this iniquitous purpose, in addition to what they get by burning the chert. If the miller wishes to separate the lime from the burnt chert before he grinds it, he may very easily do so by laying it in a heap when he takes it out of the kiln, slacking it, and riddling it as common lime, for the lime in that case will pass through the riddle, and the chert will stay there, which he may wash and use with great safety. I have lately had some flint with one sixth part of lime in its composition by weight, and a great deal more in measure."

Now follow some general observations on keeping the men efficient. From several chance remarks it would appear that the ethical standards of the men were much the same then as now; and it was necessary to provide against the frailties of the human element in the factory. He said:

> "The clerk of the manufactory should be at the works the first thing in the morning and settle the people to their business as they come in, to encourage those who come regularly to their time, letting them know that their regularity is properly noticed, and distinguishing them by repeated marks of approbation from the less orderly part of the work-people, by presents or other marks suitable to their age. Those who come later than the hour appointed should be noticed, and if, after repeated marks of disapprobation they do not come in due time, an account of the time they are deficient in should be taken, and so much of their wages stopped as the time comes to, if they work by wages, and if they work by the piece they should, after frequent notice, be sent back to breakfast time."

The clerk is then advised to visit the various shops and see that everything is neat and clean, with no rubbish swept into corners,

and that tools, moulds, etc., are in good order. He then added:

> "Workmen are extremely subject to make too much use of their sponge in smoothing their work, the effects of which appear very sensibly when the ware is glazed, especially with a thin glaze, and, as the sponge raises the flint upon the surface of the vessel, it occasions a roughness which is disagreeable on any part, but mostly so upon the edges. The use of the sponge should therefore be discouraged as much as possible in general; be absolutely prohibited upon the edges of the ware, and where it cannot be laid aside, the use of it should be moderated as much as possible."

After discussing the throwers, turners, and handlers, he comes to the pressing of plates. Here it must be remembered that pugging was not in use. The clay was wedged and slapped, apparently by the process which is in use in many of the bone-china factories. He wants the men themselves to realize what mischief the uneven tempering of the clay can do. The educative process is thus quaintly described:

> "The most general fault in all flat ware, where it is not particularly guarded against, is a wreathed and uneven surface when burnt. This evil arises from the clay not being of one uniform, even temper. I found it very difficult to persuade the men that this was the reason, but at last convinced or, at least, silenced them by an easy experiment which I made them perform themselves. I stood by whilst they slapped several pieces of clay with 40 slaps to each, of which a number of table plates were made and marked. I told them if any of these came out wreathed, I would then give up my opinion, but if, on the contrary, these came out good and free from that defect, whilst the others made in the common way, had it, they should then give up theirs and let all their clay have a given number of slaps; the plates came out good, and from that day to this, many years, I have not seen a piece of wreathed table plates. Wedging the clay as they call it, is a good preparatory to slapping. A method they have sometimes fallen into in slapping their clay, shews what shifts men will make use of to evade the performance of their duty. When they were to give the clay so many slaps, I found some of them taking large handfuls, more than they could divide in the middle, and took a little off one side, a third or a fourth perhaps, and slapped it together again. And it was with some difficulty that I convinced them, *that where they took off a fourth part only instead of half the piece it required*, of the fallaciousness of this method, or at least prevailed upon them to alter it. The pieces of clay should certainly be divided into two nearly equal parts, and the best way is, after the clay is wedged, to slap no more in one handful than sufficient to make the piece of ware. It should likewise be laid the flat way of slapping upon the board and so beaten out into the bat of which the piece of ware is to be made, and they will be much less liable to bend or warp in the drying or burning by this means."

Wedgwood follows on with a description of a few other faults likely to occur in plate-making. He then proceeds to the making of dishes, compotiers, dessert-plates, saladiers, covered dishes, tureens, sauce-bowls, creme bowls and covers, salts, leg-pans, chefing-dishes, sauce-pans, etc. He next discusses the manufacture of pieces liable to fly or crack both in the biscuit and glost ovens. He says:

> "Various means may be used to prevent entirely, or, at least to lessen

greatly, this evil. A particular clay should be used on purpose for all vessels liable to this disaster; it consists only in taking out the very finest part of the flint, and using the rest,—that is, take one of the very finest lawns, and after making the flint very thin, sift it through this finer lawn; that which goes through may be used for common clay; that which does not, is to be set apart to be mixed with the clay for vessels that are subject to crack in the oven.

The more uniform the vessels are in respect to thickness, the less liable they will be to crack, and the thinner they are, the less subject to it. A little alteration in the form of the vessel will often be of great use, and which most of these vessels will admit of without any material injury. A vessel with a flat, broad, bottom and straight sides, so as to form a sharp angle between the bottom and the sides, is the form most liable to these accidents. By making the part, therefore, a little round between the bottom and sides, they will be less liable to crack. This should be attended to in the leg pans in particular. When a large vessel of this sort is thrown upon the wheel, turned, and then oval'd, and a bottom put to it, it will, from the circumstance of having been first made and afterwards dried, in a circular form, be more liable to crack, as from a principle mentioned before it will always have a tendency to revert to its original form. Large oval vessels should, therefore, be made oval in the first instance. In making the water plates, the bottom part and the top should be either both thrown on the wheel or both of them pressed; when one is thrown and the other pressed, they acquire different grains, which never agree well together. In glazing these vessels, the inside and outside should be glazed as nearly of a thickness as possible; and they should be cooled gently in the oven, both the biscuit and the Glaze. In China, when they have large vessels in the oven, they are a week in cooling; this does not only prevent them cracking in the first cooling in the oven, but is like the annealing of glass, and tends to secure them against the effects of sudden heating and cooling afterwards when in use."

There have been several discussions in the TRANSACTIONS on saggars and on the care necessary in setting the bungs. The following is Wedgwood's contribution to the discussion:

"The men should be reminded to set the lowermost saggar of a pile upon level ground; as this is to bear the weight of the whole pile, if it has itself only a few points to bear upon, the weight of the rest is sure to crush it down and break. I have seen them thus broken two or three saggars high when the first has stood very uneven, and this is, in reality, no small cause of the destruction of saggars. It would be worth while to have some saggars made on purpose for bottom saggars, which would answer two other good purposes in guarding the other saggars from the moisture of the floor, and from the dirt which is always upon it. But even these ground saggars, where there is a vacancy between their bottom and the floor, should be supported with tile pieces, or even they would be liable to break with so great a weight as a pile of saggars upon them, when bearing only upon a few points. It being of great consequence to keep the bottoms of the saggars clean, they should never, after coming out of the repairers hands, who is supposed to clean them, be set upon the ground or placing bench without something under their bottoms."

The biscuit oven is next discussed. He emphasizes the importance of keeping the bags in good repair and well stopping them with a mixture of horse-dung and clay where required. He continues:

"The oven should be so ordered that it should fire as hard at the bottom as the top. If it fires too hard at the top, make more holes at the top of the oven, or make those you have there wider, by which means the reverberatory force of the fire acting on the saggars in the top is diminished, and the lateral force, which is continually progressive, has time to heat the bottom, before the top is too hot."

The dipping of hard and easy biscuit is described:

"Any vessels which are remarkably thin, will be deficient in obtaining a due proportion of glaze, although the thin pieces are no harder fired than the thicker ones, and it is upon this principle; if one piece of biscuit absorbs a greater quantity of water from the fluid glaze in a given time than another, that piece will have a thicker coat of glaze. A thin piece of ware, therefore, being dipped in the glaze on both sides at the same time, will be saturated with water before a sufficient coat of glaze adheres to it on each side. It will, therefore, want its due share of glaze, though dipped in that which would give quite enough to a thicker piece of ware. And this is the reason why we often find the top edges of teacups and other small ware when made very thin, quite deficient in glaze, whilst the thicker parts have a sufficient quantity. Very thin pieces of ware, therefore, as well as the hard biscuit should be sorted out to be dipped in a thicker glaze than the easier fired or thicker ware.

Another circumstance in the dipping should ever be attended to, which is the very frequent stirring it up; for as the glaze consists of two bodies of very different specific gravity, lead and flint, and as they subside or sink downwards towards the bottom nearly in proportion to those specific gravities, the flint will, of consequence, be nearest the surface when it has been a few minutes without stirring up, and this often occasions a roughness upon the surface of the ware when they come out of the glost oven, the flint in this case being in an over proportion to the lead."

His observations on drawing the glost ovens are important and instructive:

"It is equally necessary to attend to the drawing of these ovens, by which he will discover where the fire has been the hottest, what part of the oven has had too much and too little fire, whether the fire has got in amongst the saggars and ware, for want of proper attention to stopping the bags, or their failure in the burning. He should always examine when the ware is out of the oven, the state it is left in, that he may give proper directions for such repairs as may appear necessary. He will likewise, in assisting to empty the ware out of the saggars, be able to discover any errors committed in the placing of it in the saggars, and will likewise see if the saggars themselves have had justice done to them in repairing and keeping them in proper condition, and whether the stopping used is the fittest for the purpose that can be made; if it does not vitrify sufficiently to hold the pieces firmly together, he should order a little more lead to the stopping: if it fluxes too much, so as to drop out of the crack upon the ware below, then a little more flint or clay is wanted to it. This will likewise be a proper time to examine which of the placers perform their business in the best manner, that is, filled their saggars the best, with the least injury with respect to sticking, and preserved their ware freest from dirt on the inside. To such men he should no more forget to show marks of his approbation, than to reprimand those more slovenly and careless."

Wedgwood does not say much about the biscuit saggars, but he has a good deal to say about the glost saggars.

"When the saggars have come from the biscuit oven for use as glost saggars they should all of them be examined by the person who repairs the glost saggars. He should first turn each saggar with the bottom upwards, and, after brushing it, he should fill all the little cracks with a mixture of white lead, flint, and clay nottings, about equal parts, well mixed together, sifted and preserved for this purpose. The best way of filling the cracks is by a sponge dipped in this liquid, squeezing it gently and running it along the cracks; this is chiefly for small cracks. If they are large ones, another method must be used: for which purpose it will be necessary to have notting clay with a large proportion of flint in it, to prevent its contracting in burning; the larger cracks should be stopped with small rolls of this clay dipped in glost to make it stick to the saggar. The first of these mixtures I would call Stopping Slip for the glost saggars, the second Stopping Clay. Cracks in the sides of the saggars are to be stopped in the same manner.

The whole inside should then be washed with ground bone ashes mixed with a little slip. This stopping of the bottom and sides should be repeated after burnings as often as wanted, from which two great advantages will result. One is that it will prevent little fragments falling out of these cracks—when they are in the oven and opened by the fire,—upon the ware in the saggars below them. And the other is that the saggars will last as long again by this treatment, for the stopping slip and stopping clay serve as cements to hold the shattered parts together and prevent their growing worse."

Wedgwood's next point is very important. It cannot be too strongly emphasized to-day.

"They should at all times be kept dry, and none of them stay long out of the ovens, for if they do, they will acquire a dampness from the air, which will be pernicious to the ware fired in such saggars by preventing, more or less, the glaze from vitrifying, and principally on the edges and bottoms of the ware. This is a circumstance I have often proved by putting a piece of a wet brick into a saggar full of glazed ware; nearly the whole of the surfaces have been quite dry, and covered with large air bubbles like pustules of the smallpox. Every means, therefore, should be used to prevent moisture being imbibed by the saggars. If any of them have been kept out of the oven for some weeks, they should be fired the first time empty. Agreeable to this principle of moisture, when imbibed by the saggars, being injurious when thrown out again upon the ware, we have long observed, that the ware was more affected in this way, viz., with dry edges, etc., in winter than in summer, and being persuaded that the wetness of the coals in this season being all thrown upon the saggars in the first kindling of the fire, to such a degree as even to make the saggars drip with moisture, contributed greatly to the increase of this evil, we have for a long time past had the coals got into the warm hovels a day before they are wanted, and this must not be omitted."

This experiment with the damp brick is admirable in its simplicity; it cuts at a theory which we have employed for some years, under the impression that it was one of our own development. We have extended the idea, and observed a number of its ramifications. The lessons are so important, that we will take this opportunity of digressing a little from the note-books.

Water readily condenses on the unfired glaze. Thus, with a damp saggar, the steam is driven from the sides, etc., in the early stages of the firing and partly condenses on the cooler ware inside;

and thus it is subsequently driven from the ware as the temperature rises. It is not alone condensed water, but the steam plus the sulphurous vapours in the atmosphere of the kiln, forming sulphuric acid. There is plenty of evidence of this. The saucers and plates on the table for instance, show that this dilute acid has condensed on the ware and dissolved some of the cobalt blue; the solution of cobalt sulphate has trickled down to other parts of the plates. On evaporation the solution has left behind the cobalt salt, which has produced blue stains. The track of the liquid left in running to its lowest level can be distinctly seen. These plates came in the ordinary course of manufacture, and emphasize the powerful corrosive action of condensed steam. It just happens that the blue coloration is a visible and tangible proof of these statements. With white ware the proofs of the action are less direct. The condensed acid can decompose the frit, forming sulphates of the various bases in the glaze. This delays the maturing of the glaze, and in some cases produces extraordinary effects. For example, the bottoms of cups inadequately dried after dipping, may be badly "ruckled" or "eggshelly." Similarly, damp thimbles, etc., may produce effects like "sucking." The original observation of Wedgwood is thus a striking testimony to his acuteness and acumen.

XIX.—Note on the so-called Kaolin of Djebel Debar.

By A. A. Granger, Dr. Sc., and P. Bremond, Eng. E.P.C.

AMONG the various materials brought for examination to the Testing Laboratory of the Sèvres Factory a mineral called Kaolin, from Djebel Debar, attracted our attention. During the war a considerable quantity was acquired by the Factory and a portion was used to the extent of six per cent. in the manufacture of porcelain bodies. If my information is correct, a few porcelain and earthenware makers also tested this material. Certain peculiarities in the behaviour of the clay induced us to undertake a methodical research into its nature. It does not exhibit the characteristic aspect of china clay, but appears dry; furthermore, it is very tough, and shows no micaceous and quartzose residues. It is rough to the touch and does not show a clean fracture. The material was not homogeneous, but contained zones varying in hardness. A fragment introduced into a glass of water will remain unchanged for months, whereas china clay assumes a slip form after ten minutes. After trituration with water in a mortar, the material turns to glue, in which remain grains, as if the mineral were an association of two components, of which one remains inert and the other mixes with water. In order to obtain a paste, we were obliged to crush the substance with water in a rolling mill. The paste thus prepared is plastic, but not like a china clay paste; it is more sticky than binding. On careful examination, it was found that the clay consisted of two components: one having a horny appearance similar to halloysite, the second being hard and opaque, even on the edges. Analysis gave the following result:—

Silica	34·99	Potash	0·83
Alumina	34·65	Soda	0·31
Ferric oxide ..	0·22	Less by ignition ..	28·19
Lime	0·85		

The last figure is extraordinarily high, while the amount of alumina is remarkable in relation to the silica present. The material is obviously not china clay. The clay is easily dissolved by sulphuric acid. When dried in vacuum it loses 9·72 per cent. of moisture, which is unusual. These peculiarities pointed to the necessity of carrying out thermal tests. On heating, water is not given off alone. At about 500°C. acrid vapours begin to evolve, and sulphuric acid and traces of arsenic can be detected. The substance was heated in a retort to redness and the volatile matter was condensed. At the beginning, water alone is given off, but afterwards white vapours appear, while an oily liquid

is condensed. The cork connecting the retort with the condenser is strongly corroded. The distillation gives water, sulphuric acid and sulphur dioxide, but the sulphuric cannot be detected by washing the substance with water, hydrochloric acid or nitric acid. After heating at 400°, on the other hand, a change is produced, and with water a considerable portion of the sulphates is dissolved.

The test for arsenic gave 0·28 per cent. It is thought that the arsenic may have been introduced by hot springs in the neighbourhood. As stated previously, the mineral was not homogenous, but showed variations in hardness. We were able, without crushing, to separate a soft powder and hard fragments with a sieve. The analysis of the hard part gave :—

Silica (combined)	39·76	Alumina ..	34·53
Silica (free) ..	0·3	Sulphuric anhydride	0·57
Loss by ignition (SO_3 not included)			24·13

Neglecting the small amount of sulphuric anhydride, the molecular ratio is $SiO_2 : Al_2O_3 : H_2O$: : 1,97 : 1 : 3,95. These figures approximate closely to halloysite.

The analysis of the powder was :

Silica (free) ..	1·00	Sulphuric anhydride	10·10
Silica (combinated)	28·32	Water combined	19·32
Alumina	36·20	RO and R_2O ..	6·00

indicating the ratio $SiO_2 : Al_2O_3 : H_2O$: : 1,35 : 1 : 3,02. Hitherto no satisfactory explanation of the nature of the second constituent has been given. We do not know whether the sulphuric acid is a component of the mineral or whether it has been introduced by infiltration. Its properties indicate that it is a complex. The mineral does not contain kaolinite.

In view of the whiteness of the material, it might be considered valuable in china and earthenware making, but its want of plasticity is a serious drawback in the moulding, profiling and casting processes. It should be added to the body in limited quantities only, since it would be incorrect to substitute this halloysitic mineral for china clay. The presence of sulphuric acid did not cause trouble at Sèvres, but the amount, as previously stated, was only six per cent. The most serious inconvenience is the necessity to crush the clay with water in a stone or roller mill, the dissaggregation with water in the blunger being absolutely ineffective.

This work was barely concluded when another mineral, coming from Tunisy, was produced for examination. At first sight, it presented such decided analogies with the Djebel Debar mineral, that it was deemed advisable to repeat on it the same experiments as were made with the first material.

Dry distillation in a retort at red heat gave acid vapours, which, however, were not so abundant as before. The plasticity is satisfactory, and the mineral can be made up into a plastic mass

more easily than the Djebel Debar clay. The analysis showed :

Silica	42·41	Soda	0·18
Alumina	35·60	Sulphuric anhydride	0·25
Ferric oxide ..	traces	Water (180°) ..	8·90
Lime and Magnesia	?	Water by ignition	12·62
Potash	0·22		

The ratio $SiO_2 : Al_2O_3 : H_2O$ was 2,005 : 1 : 3,38 and the physical properties point to the conclusion that the material contains kaolinite and halloysite.

It was hoped to extend this research and to try a porcelain body, but the managers of the mines were not sufficiently interested in scientific work. Other halloysitic samples have been collected and experiments on the subject are being continued.

XX.—Boilers and Engines: How to Run them Efficiently.

By J. Phillips.
(Reported).

IN the opening stages of this lecture, which had special reference to the pottery industry, Mr. Phillips emphasised the lack of consideration which had, in the past, been given to this particular section of the pottery manufactory. He was, however, pleased to note that there had recently been a quickening in the right direction. Pottery manufacturers were gradually beginning to recognise that the showroom in which they placed their finished article was not the only spot on the works that could be attractive. There was another spot, which had previously been most unattractive, but which was capable of being made a far more inviting corner, and that was the stokehole or the boiler-house. It was here that there were, as a rule, many little foxes which spoiled the vine. Apparently, in days gone by, the fact had not been recognised that stoking or boiler firing was a scientific work, involving considerable knowledge. The potters were more and more beginning to recognise, however, that whilst, by employing men for their boiler-houses capable of easily wielding a shovel, and of converting their furnaces into a coal bunker, they might reduce their wage bill in that particular department, at the same time their yearly expenses were bound to suffer if physical ability alone prevailed. One could not condemn the fireman whose eye was kept constantly on the pressure gauge; for whether his production was economical or otherwise did not concern him; his business was to produce steam. Some owners of steam plants, alive to high fuel consumption, had gone so far as to ration the stoker—to his dismay; or they had bought fuel of a cheaper or poorer sort, hoping by such a procedure, coupled with inflexible firmness to cut down fuel consumption, they would somehow or other accomplish something. By chance something might be accomplished in this way, but it would be on unscientific lines, and it would fall far short of increasing the boiler efficiency. What was required was education and visualisation—not intimidation.

It was true that there were awkward firemen and engineers, men of the old school, who were dead set against any new ideas that one endeavoured to put into force, and who were most difficult to approach, for the old methods had become a habit with them, a recognised routine. Because of this, one was convinced that before any appreciable change for the better could be effected in the boiler-house of the pottery manufactory one must begin at the top, and convince the owners of the fact that the product of the steam factory was being produced at a loss, thus overshadowing the cost of

production generally of the larger factory—the main concern. It was necessary for the pottery manufacturer first of all to grasp the fact that the boiler-house could be run as a paying concern. The personal element in connection with good and bad stoking, and the necessity for intellectual ability as well as mere physical ability, were clearly seen in that one man might consume as much as 33 per cent. more fuel than another to produce the same effect.

The principal steam generator used in the pottery industry for motive power and heating purposes took the form of a boiler of the horizontal land type. The Cornish boiler was so named because its inventor, Trevithick, a Cornish engineer, first introduced this particular boiler into Cornwall 110 or more years ago. This boiler differed from every other land stationary horizontal boiler in that it was internally fired, and not externally as hitherto, e.g., the egg-ended boiler. The idea in the inventor's mind was that by placing the furnace inside the flue tube he would not lose so much heat as when he was firing the boiler externally. The Lancashire boiler was introduced in 1844 by Fairbairn, of Manchester, and it differed from the Cornish type in one respect only, viz., it had two furnace tubes instead of one. The idea in the inventor's mind in this case was one of alternative firing. The Galloway Lancashire boiler had two short furnace flues opening out into a large oval-shaped flue containing from 20 to 35 cross water pipes and from 4 to 6 water pockets at the sides. In perusing the chronological records of scientific occurrences it was very interesting to note that it was not merely a matter of getting heat out of the fire into the water, but of getting as much as possible of the available heat of the fuel into the water, as was evidenced by the gradually improved furnace conditions and the increased heat absorption capacity of the boiler. The efficiency of a furnace, using a given sort of fuel, was the proportion the available heat bore to the total heat generated in the furnace. The efficiency of the furnace was measured by the pounds of water evaporated per one pound of fuel burned on the grate under known conditions. The efficiency was expressed in a percentage indicating how nearly the actual performance attained to the theoretical.

After this brief description of the principal steam generators in the pottery industry, it might be well to visualise the various items of waste in boiler-house practice, in order that it might be seen that many and varied were the economies that could be effected relative to the production of power, and that what was produced by good boiler practice at a profit must not be wastefully consumed by bad engine practice. The raw materials used up in the process of steam production in this case were coal, air, and water. Air was got for nothing and plenty of it. It was the abnormally high percentage of excess that was the great source of so much waste. Water cost money nowadays, even though it were obtained from the canal. The costliest item was the fuel, and this point it would be

particularly worth while to consider specially.

There was a time when the theory of combustion was left to the college professors, and the engineer and manager did not worry themselves either with the theory or the practice, but simply worried the fireman. "It is your business to keep up steam," they would say to the fireman. "There is the coal pile; get at it." That might be all right when coal was in the region of a few shillings a ton. Nowadays, however, when the cost was nearer £2 per ton, something more was necessary. Similarly, it might be said that before the war the working potter did not mind very much whether he stood about waiting for steam or not; but since the war he was perforce very much keener, and if he had to wait about nowadays he was very quick to complain. It would pay no pottery manufacturer to have about him a lot of discontented workers hanging round with their attendants because the boiler-house was unable to keep them provided with sufficient steam to carry on with their work. It was very necessary, therefore, that the boiler practice of the modern pottery should be as efficient as it was possible to make it.

One might assume that when normal conditions prevailed in the combustion chamber, and the fire was 6 in. thick, the draught over the fire would be 25-100ths of an inch. Assuming that this was found to produce all the steam that was required when carrying a normal load, and that the gas in this way revealed a percentage of, say, 12 per cent. of CO_2, it was obviously ideal to maintain the draught recorded by the draught gauge. But within a few minutes the meter began to fall. What had happened? The fireman had evidently been raking his fire about and had made it unequal. Excess air was beginning to find its way through the bare patches, and the result was that, instead of getting a high percentage of CO_2, there was merely a low percentage, possibly not more than 6 or 7 per cent. The excess air was causing the furnace temperature to lower appreciably. Now how was the fireman to arrive at a conclusion as to whether his furnace conditions were right without the aid of some scientific instrument that would immediately reveal this? In the manufacture of pottery, as a rule, the manufacturer availed himself of all the scientific aids that he could possibly obtain; he never liked to work in the dark. Well, something of the same sort should clearly be done in the case of the boilers. A draught gauge was, therefore, a necessary piece of equipment in connection with a boiler. Seeing that it took some time to find out what thickness of fire and what particular draught would best carry a particular load, once having found out this, steps should be taken to see that the relative conditions were carefully preserved. The draught gauge would tell the fireman when his fires were getting thinner or thicker or clinkered. The gauge would at once reveal when something was wrong with the furnace. Immediately the finger of the gauge went down he would open his doors, level off his fire, feed with fresh coal, and bring back the finger of his gauge

to 25–100ths as before. There was a definite relation between the draught and the thickness of the fire, and the draught gauge would do more than anything else to bring this fact home to the fireman.

The lecturer said that he had heard firemen say before now: "I can make a fire which will last two hours." He might; but that was not good for a steam plant, and the gas analysis in this way would reveal that instead of getting a high percentage of CO_2 with such a fire, the percentage might not be more than, say, 6 per cent. A thick bed of fire would give a low percentage of CO_2 because of the fact that the air could not get through; the oxygen could not get to the carbon in the coal, and as a result the steam pressure went down. A recording draught gauge on a boiler would also reveal to the management exactly how many times the fireman had opened his doors during a given period. He (the lecturer) was firmly convinced that it was very largely because of the fact that the fireman had only opened his doors two or three times during the hour that so much smoke was made in boiler firing. For a fireman to do his duty and produce that efficiency that was required of him and that one was justified in expecting from him, he ought to fire at least ten times during the hour. The true ideal relationship between draught and thickness of fire could not be expected to be maintained for a period longer than seven or eight minutes without a change setting in. Therefore, a recording instrument on a boiler was a vital necessity. What was really necessary was a steam-recording gauge as well as a CO_2 recorder, because it was quite possible to get a high percentage of CO_2 which would not drive one's plant. He had known cases where the grade of fuel used was such that it required a great percentage of excess air, and the CO_2 was, in consequence, round about 8 or 9 per cent. instead of 12 per cent. as in other cases.

A great deal of trouble in maintaining steam in connection with boilers at many factories was due to the leakages in the boiler settings. An examination would prove that the valuable heat-bearing gases, instead of traversing the whole length of flue and giving the boiler a chance to absorb the heat out of those gases, were travelling the quickest way to the chimney. There were many inventions on the market for effecting economy in the production of steam for motive power, but it was generally accepted that further improvements were necessary in order to prevent heat losses, thereby increasing the efficiency. There were patent stokers, economisers, super-heaters, and the like, and each had added its quota towards efficient steam raising; but there was still the question of dealing with the hot gases between the boiler and the brickwork. Under ordinary conditions the escape of these gases through defective brickwork was considerable, and could only be remedied by making provision, amongst other things, for expansion. This was assured both vertically and horizontally by the "Hamer" system. The "Hamer" system provided a means whereby the brickwork was isolated entirely from the boiler shell at

the front, back and sides. By an arrangement which adjusted itself automatically, it provided close fitting joints in the flue passages and prevented leakage of gases, the utility of which would otherwise be lost.

Very often the longitudinal expansion of the boiler thrust backwards the wing walls of the downtake, and in course of time the space between the back of the boiler and the brickwork was considerable, thus permitting a great percentage of the hot gases to short-circuit direct to the main flue, which constituted a considerable loss of efficiency. Under the new method vertical plates were provided on either side of the boiler and the back, which were secured to the end of the boiler by an angle iron. These plates passed into a stuffing box, which was built into the wing walls of the downtake. A girder extended from wall to wall of the side flues, and running horizontally parallel with this girder was an angle iron secured to the boiler. One edge of the latter extended over the lower flange of the girder, leaving sufficient space for freedom during expansion. The space between the angle iron and the girder was filled with a non-combustible packing, which was of a yielding nature. It would be noticed that the wall ends were quite clear of the boiler, whilst the whole of the downtake chamber was effectively sealed.

When one came to deal with the circumferential expansion of a boiler it would be seen that the brickwork was often noticeably disjointed, and if in actual practice a light were applied to the broken joints or the point of contact of brickwork and boiler, the entry of cold air would draw the flame through the crevices, thus enabling one to form an opinion as to the quantity of cold air that was passing through into the side flues. It was obvious, therefore, that this cold air, coming in contact with the hot gases traversing the flues, must considerably diminish the temperature, and consequently materially decrease the efficiency of the boiler. A new method of overcoming this circumferential expansion consisted in the provision of two metal plates, one fitting the curvature of the boiler on each side. These plates were recessed to receive a round asbestos rope so as to make an effectually tight joint with the boiler shell. The plate itself slipped into a channel, against springs which were kept cool by flexible asbestos. The result was that, upon the boiler expanding, the plates, sliding into the channel, compressed the springs, and upon contraction the springs compelled the plate to follow the movement of the boiler. The plate itself was supported by set screws, the stems of which passed freely through holes drilled in a partition in the channel. The same principle was adopted in regard to the blow-off recess, and a perfectly tight joint was assured round the circumference of the boiler, where, under ordinary circumstances, the brickwork was usually in contact.

Under the old method of boiler setting it was usual, after the

flue covers had been placed in position, to build upon them three or four courses of solid brickwork. It was obvious that when the boiler expanded the whole of this brickwork transmitted the pressure to the side flue walls, thus cracking and disjointing the brickwork, and leakage asserted itself. By Hamer's new method, after the flue covers had been placed in position it would be seen that a layer of asbestos millboard was placed over the covers, thus sealing the butt joints. Over this was a filling of flexible packing. Upon the boiler expanding the flue cover was permitted to tilt on its seating, and the flexible packing yielded to the pressure. Upon contraction, the flue covers followed the boiler as it resumed its first position. With this method no pressure was transmitted to the side flue walls, and the brickwork could, therefore, be guaranteed to remain sound and solid. This method also provided a permanently leak-proof joint, and rendered easy access to the boiler shell when inspection was necessary.

In the course of his lecture Mr. Phillips dealt with steam and exhaust steam separators. He urged the fact that to use boiler feed water charged with oil not only involved fuel wastage, but was in some instances positively dangerous, and his contention was that grease should never be allowed to get into the water at all. In this district, where exhaust steam is used extensively for drying and heating purposes, the usual practice is to drain off the condensed steam from the various beds of pipes into a well or cistern and re-use for the boiler feed. From the point of view of economy this appears to be quite the thing to do. But on the other hand, the water being charged with oil (so liberally supplied to some engines), on being used again for feed water the grease comes in contact with the furnace crown and boiler plates, thus offering a resistance to conduction equal to ten times that offered by ordinary scale of a like thickness, considerably reducing the absorbtive capacity of the boiler, the heat escaping causing an abnormal rise in chimney temperature with the inevitable increased fuel consumption. The loss is indeed very much out of proportion to the reduced water account. The increasing demand for forced draught patent furnaces for the burning of low grade fuel makes the use of grease-laden water for the boiler a more serious matter than hitherto; the heat generated in these patent furnaces is so intense locally, that the furnace crowns have to be well cleaned in order to ensure the necessary rate of heat transference through the furnace crown to the body of water immediately surrounding it, especially where high pressures are carried, as the furnace crown may become over-heated and collapse. The "Algor" and similar boiler compositions had a neutralising effect upon grease, but it was better not to allow the grease to get into the water, or, at least, it should have been extracted before it got into the main supply pipe. A grease separator of acknowledged efficiency was now being made locally at Mow Cop (Staffordshire), and its method of working was as follows:—The

exhaust steam entered the separator at a point indicated, and passed into the expansion chamber above the separating vanes. It would be seen that during the expansion the heavier particles of oil and water would be deposited on the topmost separating vane and would drain to the edges and down the walls of the separator body to the collecting chamber below. The exhaust steam, now charged with oil and water in finely-divided particles, passed from the expansion chamber and entered the circular passages formed by the separating vanes; the revolving motion thus imparted to the steam when traversing these passages, set up centrifugal action, thus flinging all water and oil which had been held in suspension to the separator walls. At each complete revolution of the steam the current was changed by the vertical walls in the vanes and diverted to the next lower passage. This changing of the steam course acted as a baffle, and concentrated the oil and water for centrifugal separation at the next revolution. After the steam had traversed the circular passages all oil and water had been eliminated, and the steam took an upward course through the central pipe, perfectly clean and dry, to the outlet branch at the top. The oil and water of separation were drained away from the collecting chamber at the bottom of the separator, and by employing suitable apparatus the oil could be recovered and used again for minor lubricating purposes.

In the concluding stages the lecturer, dealing with the economical consumption of steam, emphasized the importance of maintaining as high boiler pressure as possible. It was a common experience to find boilers being worked at anything from 45 to 80lbs. pressure, and in some cases the owner possessed an insurance guarantee for a much higher working pressure. It is much more economical and efficient to run the boiler at high pressure, say, 120 or 160 lbs. per square inch. providing there exists efficient means of controlling steam consumption. However, where style or make of engine necessitates a low pressure steam supply to ensure a fair margin of safety, the introduction of a reducing valve such as the "Foster Patent" class "W" or "G" Type full bore, would meet the difficulty by enabling the owner to run his boiler at a much higher pressure and at the same time providing a uniform low pressure. The reducing valve acting also as super-heater would give dryer steam, and prevent damage to pipe joints and cylinder, ensuring greater economy. The speaker further added that, where live steam instead of exhaust was used for drying purposes, considerable advantage could be gained by installing reducing valves, the low pressure delivery being constant, regardless of any variation that might occur in the source of supply.

XXI.—The Geology of the Bournemouth District.

By Henry Dewey, F.G.S., of H.M. Geological Survey.

THE area with which I propose to deal in the present paper extends from Wareham eastwards to Christchurch, and northward from the Isle of Purbeck to Wimborne. In this area the following geological formations are represented:

Recent	Blown Sand. Alluvium. Peat.	Eocene	Bracklesham Beds. Bagshot Sand. London Clay, Reading Beds.
Pleistocene	Brickearth. Valley Gravel. Plateau Gravel.	Cretaceous..	Upper Chalk.

An observer standing on the cliff above Bournemouth pier will be impressed by the view extending southwest, south and southeast of him. To the southwest he will be attracted by the white cliffs at Old Harry, which are the seaward termination of the range of downs above Corfe, while southeast the white chalk cliffs of the Needles similarly terminate the great range of downs that crosses the Isle of Wight. Separating these two ranges there are several miles of sea, but even so, it is not difficult to realize that formerly the chalk formed a continuous range between the two ranges of downland.

If the land lying north and northwest of Bournemouth be viewed from a high point, another range of downs appears on the skyline. These also consist of chalk, but whereas the strata of the Isles of Wight and Purbeck incline northwards, those of the northern downs dip south. The whole area forms part of the Hampshire Basin, the axis of which lies approximately parallel with the Solent. The southern rim of this basin is marked by the bold chalk ranges, already mentioned, of the Isles of Wight and Purbeck where the strata are vertical. In the centre of the basin the beds dip at low angles usually of not more than 1 degree. Within the basin, minor undulations lead to its local flattening, and these subsidiary folds are arranged *en échelon*. They modify each other and one effect is seen where the syncline, near Wimborne, disappears, while the fold beneath Poole harbour increases. The chalk forms a continuous layer upwards of 1,100 feet in thickness beneath the sands, loams and clays of the New Forest and Bournemouth districts, and wells and boreholes if sunk to a sufficient depth, would everywhere meet with this formation.

As it is impossible within the limits of a short paper to describe all the formations in detail, attention will be called to those which possess the greatest interest to the members of the Ceramic Society and to which they intend to pay visits.

Beds of clay overlie the chalk. These belong to the Reading Beds and the London Clay. They are dug for the manufacture of red bricks, pavers, drain-pipes and tiles at Corfe Mullen, and also at Wimborne and Lytchett Matravers.

Overlying these clays, both in the Isle of Wight and on the mainland, the sands and clays of the Bagshot Sand formation occur; and the strata of the Poole and the Bournemouth district can be matched with those on the eastern side of Bournemouth bay from Alum Bay northwards. These beds belong to the Tertiary division of the geological formations. They were deposited under the sea or in estuaries and river valleys at a time long posterior to that of the chalk and during a period when the land was steadily sinking below sea-level. This formation is of great interest on the present occasion as it forms the cliffs that extend from Poole Head to Bournemouth, and contains the beds of clay that are exploited for the manufacture of pottery, etc. It has long been studied in detail by many observers and especially by Mr. Starkie Gardner, who has made an exhaustive investigation of the remains of fossil leaves, fruits and seeds of plants found in these seams of clay. In Alum Bay, these beds attain a thickness of 600 feet. A seam of clay lying about 200 feet above the base of the deposit is full of leaves of sub-tropical trees belonging to figs, laurels, aralias and also of pods of leguminous plants and fragments of the fan-palm. Mr. Gardner says of this flora that its distinctive feature "is due to the size and variety of the leaves ascribed to the genus *Ficus* and to the *Leguminosæ* in a scarcely less degree to a deeply cleft palmate *Aralia*, a trilobed leaf resembling *Liquidamber*, a deeply serrate *Banksia*, and other leaves referred to *Comptonia*, *Dryandra* and *Myrica*.[1]

These leaf-bearing clays lie among what appear to be the delta-deposits of a large river, which probably arose somewhere south-westward of Hampshire, and not unlikely upon the granite uplands of Dartmoor. If the clays were derived from Dartmoor, they drew their material from the felspar of that granite mass. But as the eastern parts of Dartmoor are only slightly kaolinized, it is not unlikely that the river drained the South-western part of the moor, where widespread kaolinization has affected the potash-felspars.[2]

The Bagshot Sand covers a wide area extending from Wool Heath through Wareham, Poole and Wimborne to Boscombe, but the lowest or Pipe-clay division forms only an irregular patch of ground west of Poole Harbour. The pipe-clays are best developed around that harbour and pass northwards into more silty beds that have not been worked. On the south of the harbour white and mottled clays occur in the small islands, while on the southern side of Brownsea, the clay has been dug to a depth of some 25 feet, and

[1] "British Eocene Flora," pt. 1, p. 16. *Palæontographical Society*, 1879.
[2] See also Composition and Manufacture of British Pottery and Porcelain, 2nd Edit. (*Mem. Geol. Surv.*, 1871, p. 5).

pipe-clay was formerly got near the northern end of the island.

Good sections of the pipe-clay bed, upwards of 25 feet in thickness, can be studied on the north side of Poole Harbour, especially at Lake Clay Works and near Hamworthy Junction, and can also be seen at the Kinson Potteries and other works north of Parkstone. An inlier of pipe-clay occurs in Bourne Bottom, and many sections are exposed in road cuttings near Parkstone, Beacon Hill and Broadstone.[3] Further to the south it was worked at the Matcham Clay Works and at the Norton Pits, and for miles towards the foot of the chalk ridge the refuse heaps of these excavations for pipeclay seam the brown heath with a line of mounds[4] At the Matcham workings there were 30 feet of variegated pipe-clay and 8 feet of pure "Potter's Clay." The latter is described as "a soft, white, and somewhat unctuous clay," and is no doubt pretty nearly pure kaolin[5].

It is not known when Poole clay was first worked. By an order in Council of 1666, arising out of a dispute between Wareham and Poole, it is directed that no dues were to be paid on "tobacco-pipe-clay." In an act of Parliament obtained by Poole, in 1756, the clay is termed "tobacco-pipe-clay." Hutchins in his *History of Dorsetshire*, published in 1774, mentions this clay as the chief article sent from "the Key at Wareham," and in 1796 about 10,000 tons of it were exported annually. (Hutchins remarks that the clay was dug round Wareham at Arne Hill, Heneger Hill,Norden, on Norden and Witch farms).....Many of the clays termed *pipe-clays*, from being used in the manufacture of tobacco pipes, appear to have been derived, not directly from the decomposition of crystalline rocks, but rather from the disintegration of pre-existing stratified rocks. Mr. Maw has suggested that some of the finer white clays of the lower Tertiaries may have been derived from the chalk[6]. Rudler (*Op. cit.* p. 27) gives the following analysis by Mr. W. Weston of a sample of Poole clay:

SiO_2	.. .. ..	48·9
Al_2O_3	.. .. ..	32·11
K_2O	.. .. ..	3·31
CaO	.. .. ..	0·43
MgO	.. .. ..	0·22
Protoxide of Iron	.. ..	2·34
Water { combined	.. ..	9·63
Water { hygroscopic	.. ..	2·33
		99·36

[3] H. J. O. White *in* "The Geology of Bournemouth," (*Mem. Geol. Surv.*, 1917, p. 20).
[4] W. H. Hudleston *in* "A Record of Excursions," Geologists' Assoc., 1891, p. 321.
[5] *Op. Cit.*, p. 322.
[6] F. W. Rudler. "Handbook to British Pottery and Porcelain," (*Mem. Geol. Surv.*, 1893, p. 5).

The output of clay from Dorset and Hampshire during 1919 amounted to 72,378 tons and 49,018 tons respectively[7]. W. Starkie Gardner described the beds overlying the Poole pipe-clays as the Bournemouth Freshwater Beds. They consist of white and yellow sands with finely laminated lenses of carbonaceous clay or loam and some rather impure pipe-clay. These lenses range up to a few hundred yards in length, and have often yielded an abundance of plant remains representing a much more varied faema than that of the Poole beds, and including conifers, ferns, palms, fungi, deciduous trees and marsh plants. The lower beds contain willow, the middle beds palms and ferns, and the upper beds arancaria, eucalyptus, etc. The cliffs between Poole Head and the Lift east of Bournemouth Pier, shew very fine sections of these sands. They may be as much as 400 feet in total thickness[8], and are overlain by the Bournemouth marine beds, including the Boscombe sands, which may attain together a thickness of 300 to 400 feet. They consist of fluro-marine sands and dark laminated clays and are exposed in the cliffs east of Bournemouth Pier, overlain near Boscombe by the yellow and white sand with beds of shingle of the Boscombe sands.

These sands appear to represent the landward deposits, bars and shoals of a subsiding sea bottom. A few hundred yards east of Boscombe Chine, there is a mass of coarse shingle upwards of 30 feet thick, which Prestwich described as the "most important conglomerate bed in the English Tertiaries,[9]" The characteristic feature of this coast is the number of chines along it. They present various stages of growth from the merest beginning at Meyrick Steps, through vigorous childhood at Honeycombe Chine to old age in the valley of the Bourne. They invariably have a small stream down their centre, sometimes carried through drainage pipes but well seen in the Bourne, and owe their origin to the activity of these streams. The main beds of clay arrest the downward percolating rain water, which washes out the finer sandy material and so leads to collapse, in time, of the overlying beds, and the gradual widening of the chine[10].

The Boscombe sands gradually dip eastwards beneath the Hengisttny beds. These are sub-littoral marine beds deposited in moderately deep water and are divided into a lower series 12 feet thick and an upper one 49 feet thick. The principal point of interest, economically, attaching to these beds, is the occurrence of the concretionary iron-ore. This was dug on the northern and western sides of the headland and gathered from the foreshore for a period of some twenty years from 1847, and shipped to South Wales and Staffordshire. The concretions contain about 30 per cent. of iron.

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[7] Home Office Returns and Statistics, 1920.
[8] J. S. Starkie Gardner, *Quart. Journ. Geol. Soc.*, 1879, pp. 209-228.
[9] *Quart. Journ. Geol. Soc.*, Vol. V., 1848, p. 47.
[10] *See* W. T. Ord, "Scenery of Bournemouth," *Trans. South-Eastern Union of Scientific Socs.*, 1914, pp. 24-25.

Capping the cliffs between Poole Harbour and Hengisttny Head, a series of gravels will be observed. These form parts of a once continuous spread, which extended inland over the area of the Tertiary deposits. Many of the highest parts of the New Forest are formed of these gravels, which, on account of their general wide-spread occurrence in upland flats, have been termed plateau gravels.

Their mode of origin is unknown, but it is, not improbably, some form of glacial agency. They are in part more ancient than the terraces that border the modern rivers, but like the highest of these terraces contain numerous flint implements of palæolithic workmanship; but remains of extinct beasts such as elephant, rhinoceros and the like, occurring so abundantly in the terrace gravels, have not yet been found. Specimens of these implements are sometimes picked up on the shore at Bournemouth.

ERRATA.

The proofs of pages 296-7 inadvertently went to press uncorrected. The following alterations should be noted:—

Page 296,	line 8.	For "fæma'	read "flora."
,,	,, 11.	,, "arancaria"	read "araucaria."
,,	,, 17.	,, "fluro-marine"	read fluvi-marine"
,,	,, 37.	,, "Hengisttny"	read "Hengistbur".
Page 297,	line 1.	,, ,,	,, ,,

XXII.—Some New Forms of Kilns.

By Sir A. Duckham, K.C.B., M.I.C.E.

At the last Autumn meeting of the Refractories Section of the Ceramic Society, I promised Dr. Mellor I would place before you some designs of kilns which presented novel features. Although some of these are not specially adapted to refractory work, they may interest you and will show the line of thought followed in our designs. My firm, as you may know, were primarily interested in the construction of plants for the manufacture of coal gas. We required for our purposes large quantities of high-class refractory material. The temperatures we wanted in the combustion chambers around our retorts were considerable, —1350°C. In the earlier stages we had the greatest difficulty in obtaining suitable material, in fact we suffered heavy losses through the failure of the materials used. But for these circumstances we probably should not have taken up research into and manufacture of refractory material.

In 1914 we were instrumental in the formation of a Firebrick Manufacturing Company, and undertook the design of a kiln that would ensure the proper burning of our refractory materials, together with a due economy of fuel. We were already closely in touch with the manufacturers in the Stourbridge area, and it was in that district we placed our works. The design of the kiln we erected was based on an existing plant in Germany in the works of our agents, and during eight years it has given general satisfaction. The kiln is of the continuous type, 16 chambers in all, each chamber 19 ft. 1½ in. wide by 16 ft. 9 in. long by 6 ft. 0 in. high to the springing of the arch, and 10 ft. 5 in. high to the crown of the arch. The chambers are arranged in two lines, with wickets on the outside only. There are four fireholes and bags to each chamber, the arrangement of firing being that generally known as semi-gaseous. Figures one to three will show the general lay-out.

One of the chief questions in design was to settle whether to heat the kiln by an outside producer or by four individual fireholes to each chamber. In Germany the outside producer was used, consuming brown coal. We adopted the individual firehole system, as we felt that the advantage of getting hot gas to the point of combustion in the bags would make up for the disadvantages attendant to individual fireholes. The results of working have justified our decision, and for this form of kiln, with four bags and down draught, the firing arrangement adopted gives excellent results. We burn firebricks in this kiln made of local clay and reinforced with clay grog and silica. The bricks are burned till Cone 13 comes down in the centre of the material, and this temperature is held for about 12 hours. Each chamber holds

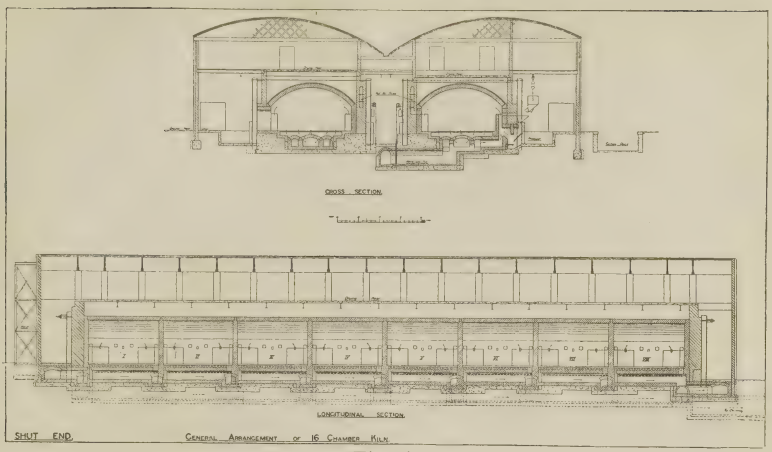


Fig. 1.

60 tons of material and we burn 14 to 15 chambers per month. The fuel consumption is 20 to 25 tons of coal per 100 tons of material.

I would now put before you the disabilities of this kiln as constructed. The chief trouble we had was to obtain sufficient draught to be able to work two chambers ahead of the firing kiln in order to utilise the heat in the flue gases, and two chambers behind to properly heat the secondary air. The chimney was 180 ft. 0 in. high, but as the temperature of the flue gases was only 120°F., entering the chimney, the pull on the main flue was insufficient.

The low temperature of the flue gases entering the chimney was partly due to the full utilisation of their sensible heat in the

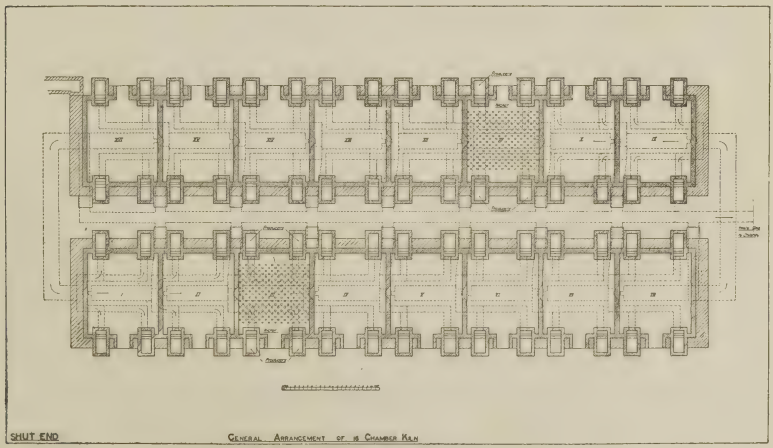


Fig. 2.

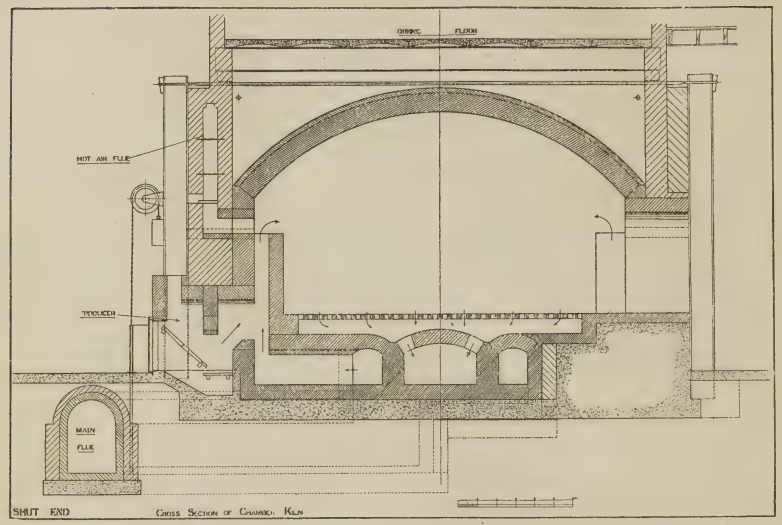


Fig. 3.

chambers ahead of the firing chamber, and partly due to air leakages chiefly through the main dampers to each chamber. The dampers, as you will notice in the diagrams, were of the vertical cast iron type, and it was found impracticable to keep these air tight either around the sides or at the top. Consequently these dampers were replaced by cast iron flap doors. This change ensured tightness at this point, and greatly improved the draught. We still found, however, that we could not, under all weather conditions, be certain of obtaining in a reasonable time and under all conditions the high temperature of burning which was absolutely essential in order to ensure that the shrinkage had been eliminated from the firebrick material. We consequently decided to dispense with natural draught altogether, and installed artificial draught with most satisfactory results. The output from the kilns is greater and we can be sure of the proper burning of the material. Recent tests on the product of this kiln show a shrinkage of between ·25% and ·75% when heated for two hours at 1410°C. actual.

Another difficulty we had to meet is inherent to the principle of a down draught kiln. The material at the top was burned to a higher temperature than the material at the bottom, and if the bottom temperature was raised to a proper degree there was grave danger of the upper material being damaged. As we proposed to extend the output of this works, we had to consider and overcome this difficulty and had to decide to depart from the principle of either an up-draught or down-draught kiln.

Figures four to seven illustrate the W.D. Central Bag Kiln.

Dr. Mellor has put this kiln previously before you and it will, therefore, need but short description.

Its advantages are:

(1) That even heating is obtained throughout the whole of the material of the kiln;

(2) That the bag forms no portion of the kiln proper, and so can be made of different material, and further it can be easily renewed;

(3) Proper combustion of the heating gases is assured;

(4) The brickwork forming the kiln proper is never subjected to the direct action of the heating gases during combustion.

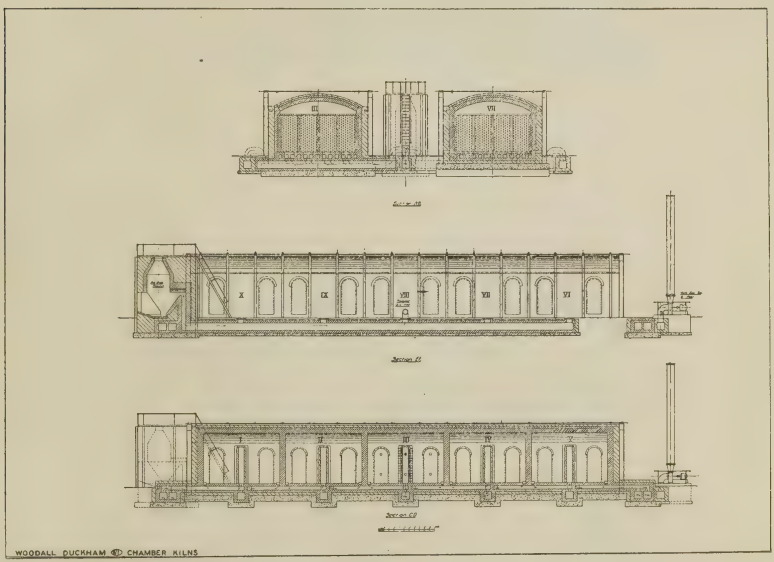


Fig 4.

A single chamber, 15 ft. 2 in. wide by 16 ft. 8 in. long by 7 ft. 6⅝ in. to the springing of the arch and 10 ft. 9⅝ in. to the crown of the arch, has been constructed on these principles with an outside producer burning coal and has given satisfactory results. We are shortly erecting a continuous chamber kiln on these lines. The high temperatures required for the proper burning of refractory material and the comparatively long period of soaking required at that temperature precludes to a great extent the use of kilns other than the continuous chamber type for this purpose. In fact, for the burning of silica material, where an even higher temperature of firing and a longer period of soaking is essential, further

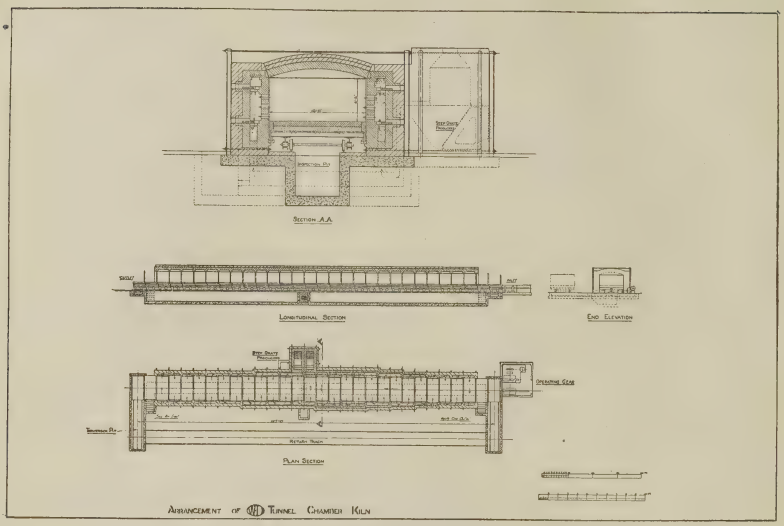


Fig 5.

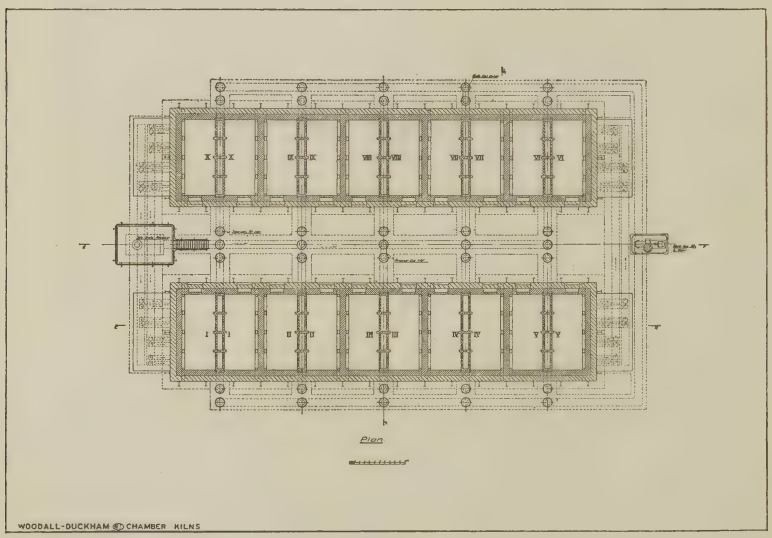


Fig. 6.

modifications in continuous kilns must be made to obtain satisfactory working. We are at present designing a special kiln for burning silica bricks, and when these designs are completed I trust an opportunity may occur for them to be put before you.

The design of kiln which has always attracted the designer is

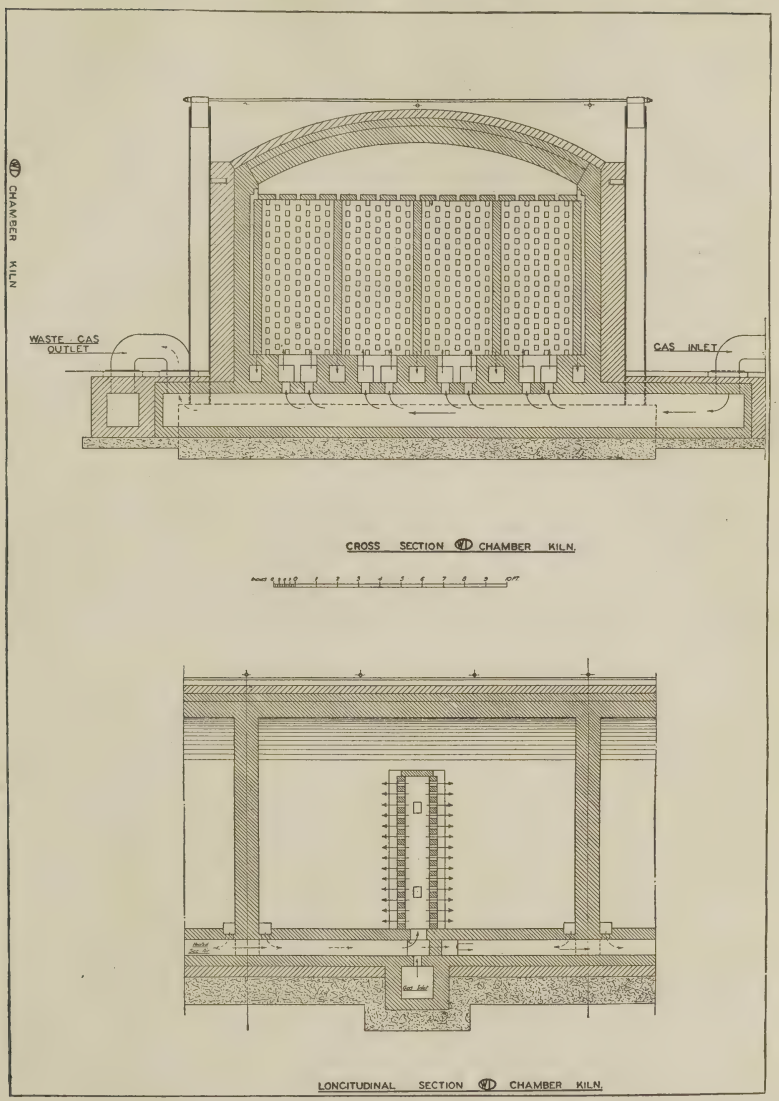


Fig. 7.

the tunnel type. This type has not proved satisfactory for the burning of refractory material, but I venture to put before you two modifications, as I believe consideration of them may interest you and may lead to further developments. The advantages of a tunnel kiln are very evident—saving of labour and fuel and even heating and cooling of the materials. The disadvantages are:

(1) Mechanical:
(2) The great length of the tunnel:
(3) The tendency of the heating gases to rise, and so cause uneven burning.

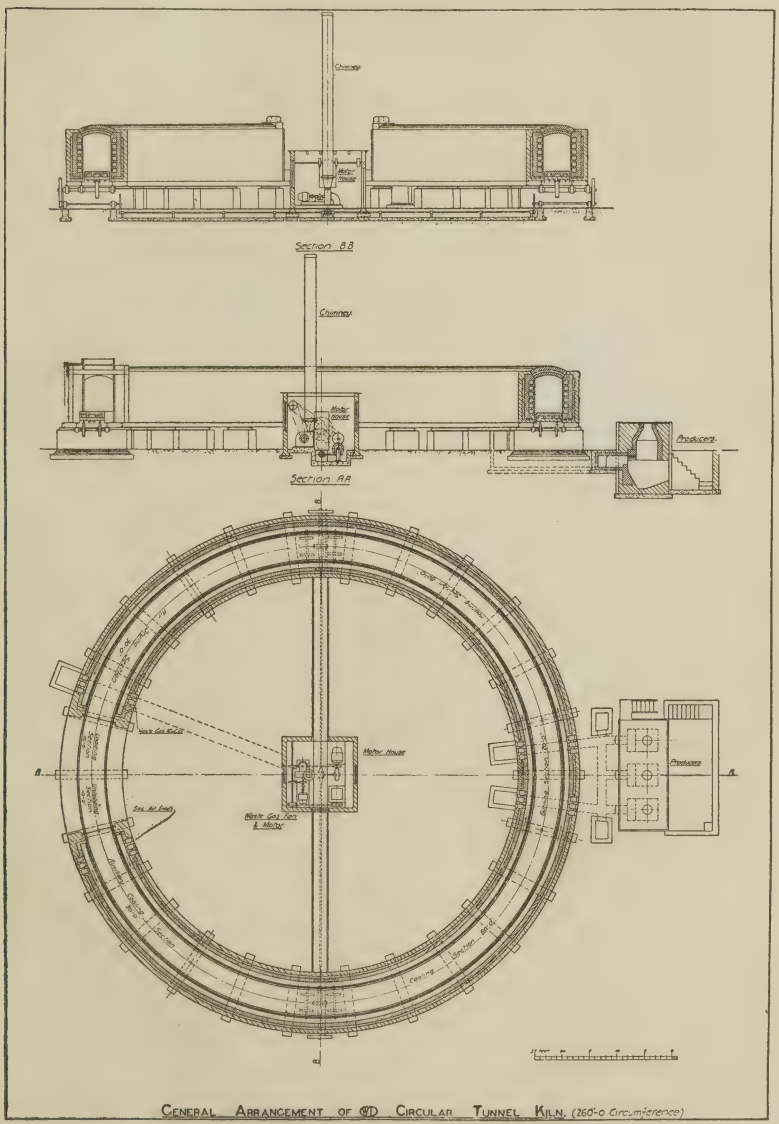
Dealing first with the open type of tunnel kiln, we have endeavoured to overcome the difficulties in the following ways:—

Instead of allowing the gases to pass straight through the whole length of the kiln, cross walls are provided on each truck carrying the material, these cross walls registering with offsets on the kiln walls, thus forcing the gases to take a zig-zag path instead of a straight one. By this means we are able to reduce the length of the kiln from, say, 300 ft. to 130 ft. These cross walls really divide the tunnel up into a number of chambers, short flues in the side walls being provided to carry the gases from one chamber to another. In order to ensure the material heating throughout its height when piled on the truck, the openings for the passage of the gases are only made in the lower portion of the flue walls, thus ensuring the heating gases flowing across the lower parts of the material as well as around the upper parts. Combustion takes place about the centre of the kiln, the heating gases following a zig-zag path to the end at which the material enters. The cooling air is let into the exit end of the kiln, following a zig-zag path and becoming more highly heated until it reaches the point of combustion.

Arrangements are made by which an excess of air may be admitted in order to ensure proper cooling and to enable the excess to be drawn off before the combustion point is reached. The trucks carrying the material in this kiln shown are 5 ft. 0 ins. long by 10 ft. 0 ins. wide and are travelled five feet at a time. Arrangements are made to prevent bye-passing around the ends of the division walls on the truck and over the top. It will be seen that this design greatly reduces the length of the kiln, provides for even heating over the cross sectional area of the tunnel, and removes any difficulty in cooling the material. The trucks are sand-sealed about at the bottom, and a ventilated pit is provided through the length of the kiln beneath the truck bottoms, so that ready attention can be given to any mechanical part.

A problem which was recently put before us was the proper burning of large glazed goods in a muffle. The material was to be slowly and evenly burned at a temperature of about 1100°C., and slowly and evenly cooled. For this purpose we designed an annular circular tunnel kiln, with the heating gases muffled (see figures eight and nine). The continuity of the tunnel is broken at the unloading and loading point, but the annular fire-brick tray carrying the material is continuous and unbroken. The heating of the kiln is by means of producer gas burned in six horizontal flues arranged one above the other in the side walls of the tunnel.

These flues being separated throughout their length, the intensity of heat to the various parts of the kiln is controllable and an even temperature preserved through the height of material. The tray is moved by electric motor and gearing ten feet at a time, the operation taking some 30 seconds.



GENERAL ARRANGEMENT OF 60'D CIRCULAR TUNNEL KILN. (260-0 Circumference)

Fig. 8.

The combustion zone is approximately opposite the unloading zone and the heating gases flow toward the inlet end for the material. Mechanical draught is applied by means of a fan and motor. Cooling is controlled by the admission of air into the muffled flues about the outgoing material and a regulated supply of air is admitted inside the muffle at the exit end to ensure the final cooling. Special arrangements are also made for warming and removing the moisture from the unburned materials as they enter the kiln. The chief advantages of this kiln are convenience of working, elimination of trucks, even heating and economy of fuel. One of these kilns will be working early next year, but the principle has been proved on a kiln of similar design forming part of a chemical process. In designing these kilns we have tried first

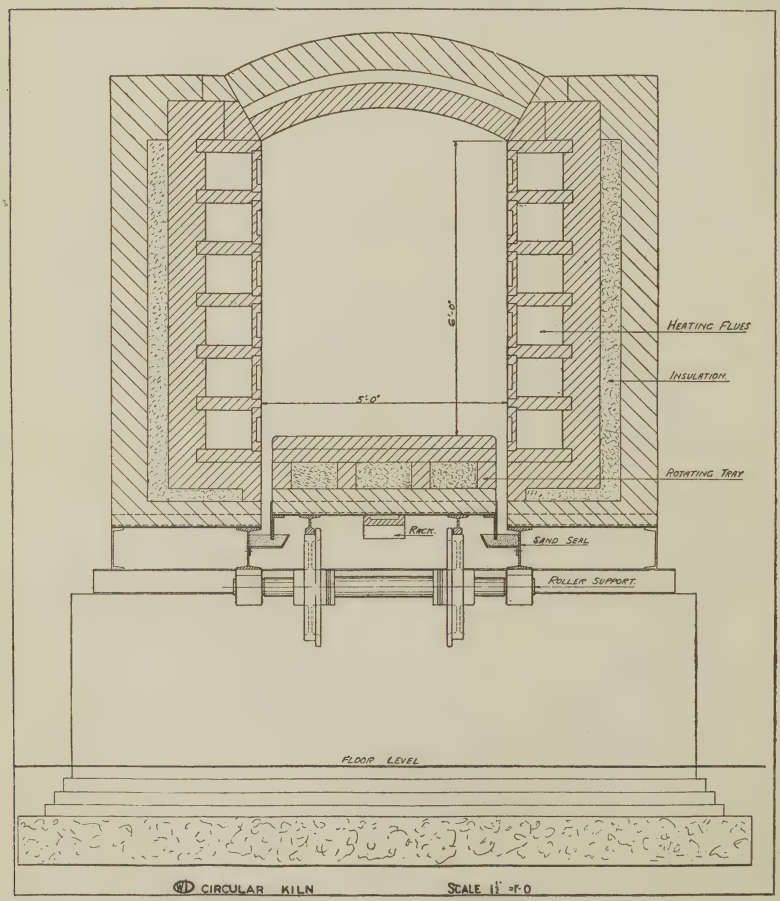


Fig. 9.

of all to grasp the fundamental needs of the manufacturer. These, of course, vary very greatly, but once they are fully understood, the work of design is not so difficult a matter.

DISCUSSION.

MR. A. B. SEARLE:—Do I understand that the straight tunnel kiln with the zig-zag motion of the gases has actually been built?

SIR ARTHUR DUCKHAM:—No. That particular kiln has not yet been built.

MR. SEARLE:—The short kiln is so extraordinarily interesting that one feels one would like to hear more about it.

SIR ARTHUR DUCKHAM:—I may say that that kiln was put before some of our friends in the Potteries district, and we offered to put the kiln up without asking them to pay anything at all for it unless it worked satisfactorily. But we have not yet found anyone sufficiently enterprising in the Potteries to take it on.

MR. G. E. STRINGER:—It would be rather interesting to know what degree of draught the chamber kiln is worked under and what is the rate of progress. I think that if a diagram could be presented by Sir Arthur Duckham showing the rate of heating up and cooling down it would be very helpful.

SIR ARTHUR DUCKHAM:—I have not a diagram with me but I might add the following information. The speed of burning that I gave was 14—15 chambers per month, and, of course, the chambers have worked continuously right through. Each chamber will, therefore, be under direct fire for 48 hours, and we propose working two or three chambers before the kiln under fire, and two chambers behind. These data give the time for heating up and cooling down. The kiln under fire would be worked with practically a level gauge at the top of the kiln, and with a slight negative pressure—say $\frac{1}{10}$ inch. water—at the bottom.

MR. STRINGER:—I would like to ask if, in connection with the chamber kiln with the central bag, the combustion of the gases is quite complete and the atmosphere in the whole of the chamber oxidising. What I am anxious to get at is: would it do for firing glazed goods?

SIR ARTHUR DUCKHAM:—Of course the completeness of the combustion in practice depends upon the size of the interstices in the bag wall. If you have these very large you will have flame projecting through into your material, for the flame comes up inside the bag and some of it will come through. If you have smaller and more frequent interstices you will get surface combustion. As to whether you will get an oxidising or a reducing atmosphere, this depends very much upon the regulation of the heating gases and of secondary air. With sufficient secondary air you will have a fully

oxidising flame, for in this event you will simply get the products of combustion coming through the bag instead of the flame.

Mr. Stringer:—But if you fire glazed goods in that chamber you must not have a neutral atmosphere but an oxidising atmosphere.

Sir Arthur Duckham:—I quite agree with you, but I think when you come to deal with glazed goods you must get down first of all to the cleanliness of the atmosphere in which you are going to put them. I should hate to see ordinary producer gas put through direct on to the glazed goods, unless it had first been thoroughly cleaned. But so far as the actual burning is concerned, you can get your combustion complete in the central bag wall and take only the products of combustion through, and if you work with pure gas and filtered air I do not see why you should not burn glazed goods quite efficiently in that particular kiln.

Mr. Stringer:—I think that Sir Arthur has resolved my doubt as to the feasibility of firing glazed goods in this kiln when he talks of first cleaning his gas. Presumably that would take some form of washing. He states that there is no difficulty in controlling the atmosphere and were washed or cleaned gas used, presumably sulphurous vapour would be removed from the gas. It is essential, I think, that sulphurous vapours should not pass through goods glazed with lead glazes. I should like to ask what effect cleaning or washing of the gas would have on its calorific value? Presumably it would also result in entire loss of the sensible heat of the gas.

Mr. H. J. C. Johnston:—I should be glad if Sir Arthur Duckham could amplify his statement with regard to mechanical draught—particularly in connection with the coal-fired kiln with which he first dealt. What firebrick and silica brick manufacturers are on the lookout for is something either gas-fired or coal-fired which will burn at a cheaper cost and with equal or greater efficiency than the apparatus we have at present in use. I remember at one meeting, you, Mr. President, mentioned that you were burning fireclay goods in Stourbridge with $2\frac{1}{2}$ to 3 cwts. of fuel per ton of fired goods. But the figures I understood Sir Arthur Duckham to give worked out at something like 4—5 cwts., burning to cone 13. We are burning in a 20-year old Hoffman kiln to cone 13 with 3 cwts. of fuel to the ton of fired goods, and we have no mechanical draught. I understood Sir Arthur to say that he, as a user of firebricks, would not employ any bricks that were burned to that heat where mechanical draught was not employed. I think it would be interesting from the manufacturer's point of view if he were to explain that statement a little further.

With regard to the gas-fired kiln, the problem with which Sir Arthur is dealing is a most interesting one to the firebrick makers, and more particularly to those who are desirous of employing a

kiln for glazed goods and other fireclay commodities as well as firebricks. So far as we are at present aware—and many of us have investigated the subject pretty closely—there is only one chamber gas-fired kiln as yet on the market which may be said to meet the requirements of the trade, and unfortunately the terms and conditions of the installation of that kiln are such that comparatively few people have decided to adopt it. If Sir Arthur Duckham can produce a kiln which will give the results which are being obtained in the kiln to which I have referred, and enable manufacturers to burn glazed goods of all kinds, as well as firebricks, and possibly silica bricks in one and the same kiln, and put this on the market upon reasonable terms, I am sure he will confer a very great benefit upon the clay trades in general.

I am not quite clear from the diagram that was shown to us how uniformity of burning is to be obtained in the gas-fired chamber kiln with a central bag wall; this is a point which, perhaps, Sir Arthur will explain.

Mr. J. H. Marlow:—I would like to ask Sir Arthur if he is really serious in stating that in all cases the highest temperature is found at the top of a tunnel kiln. I understood him to say that it is impossible to overcome that difficulty. All I know is that I have overcome it, and can easily arrange my kiln so that it will be either hotter at the top than the bottom, or the same from top to bottom, or hotter at the bottom than at the top. This has been proved by tests made by Mr. Bernard Moore during the last few weeks. I can arrange, if necessary, to have a temperature 35 degrees higher at the top than at the bottom or *vice-versa*. So that I naturally demur from Sir Arthur's general statement that tunnel kilns are necessarily hotter at the top.

Sir Arthur Duckham:—I do not pretend that the results in the direction of fuel economy obtained with the kiln that I at first described to you are anything wonderful. They are simply the actual results of practical working year in and year out—the fuel results obtained when burning a brick to the necessary high temperature under normal conditions. I may say that I am in a sort of dual position in this matter of firebricks, because I happen to be the chairman of a company which manufactures them and I am also the chairman of a company which consumes them. I do not know whether it is a case of set a thief to catch a thief, but certainly I can assure you that the manufacturer does get looked after rather sympathetically by us, because of the fact that we are manufacturers ourselves. The figures that I have given you are, as I say, actual figures obtained with ordinary *slag* coal obtained in the Stourbridge area, working month after month, year in and year out, without any special arrangements for fuel economy.

So far as mechanical draught is concerned, all I know is that, since we have had mechanical draught, the quality of our product is much more constant and satisfactory than it ever was before, when

we worked with natural draught. Furthermore, we have found in working upon vertical retort installations that the mechanical draught gives us altogether more even and more efficient working than natural draught. I fail to see how, if you are working a continuous chamber kiln with natural draught, you can ever hope to get an absolutely even draught on your kiln under vastly varying climatic conditions. On one day you can hardly get your heat up; on another day, if you have a big wind, your material is apt to be overburnt and spoilt. Under the older conditions of firing there is far too much left in the hands of the burner to get good results in the finished material. Far above the consideration of fuel economy must be placed uniformity of product and certainty of working. On many occasions I have known the burner of fireclay goods to scratch his head and wonder how he was going to get his kiln up. At times, also, it is practically impossible for the burner to get his secondary air through his back kilns. With mechanical draught all these difficulties are obviated.

I repeat that the kiln can be used for the burning of glazed goods, but, as I say, I should not like to see glazed goods burned in an open kiln unless clean producer gas and clean air are used. I have a profound respect for glazed goods, and would strongly recommend any manufacturer who aims at getting spotless, stainless glazed surfaces to make sure that he first of all uses clean producer gas and, secondly, filtered air.

Lt.-Col. C. W. Thomas—We are very much indebted to Sir Arthur Duckham for the very interesting paper that he has given us. He has brought out the essential requirements of a kiln very clearly, and one thing that occurred to me whilst he was describing his slides was this: there may possibly still be—although I am glad to say they are getting fewer every day—people who fail to see the advantages that are likely to accrue from systematic research into the question of ovens and kilns. I think Sir Arthur Duckham has already brought out that point very well in his paper, because it is quite evident that a very great deal of thought and consideration has been given by Sir Arthur and his firm to the requirements of the manufacturer from the point of view of his kilns. Sir Arthur mentioned incidentally that he had looked through a good many kiln specifications, and that as a result of that inspection he had a certain amount of sympathy for the people who designed these kilns and tried to make them work. I can quite share in that sympathy, for I have myself looked through all the kiln specifications that I have been able to get hold of, going back to about the year 1854, and one thing that has struck me very forcibly indeed in connection with them is, that you can turn up specification after specification, and you can see that the designer has had in mind the same objects and the same difficulties as his predecessors, and that he has been dissatisfied with what has been done before in the way of overcoming these difficulties. Con-

sequently he has been driven to introduce some modification. The same lines of thought run through practically the whole of the specifications, the same ideas are tried out again, but possibly with some slight differences in detail. For many years I have regarded the kiln as the most important part of the refractory materials manufacturer's plant. I was very much interested in the tunnel kiln, a diagram of which Sir Arthur showed, because it has always seemed to me that one of the essential requirements of a tunnel kiln is adequate control of the circulation. Various attempts have been made to meet this—drop arches in the roof, recesses in the sides, flues in the deck of the cars and all sorts of contrivances—many of them complex and, therefore, inviting trouble and a very heavy repair bill. It is my strong belief that one of the essential features of any kiln, if it is to be successful in work, is that it must be simple; there must be a total absence of all unnecessary complications. It is quite an ordinary thing to pick up a specification of a tunnel kiln or a continuous chamber kiln and to see a perfect network of flues and a profusion of dampers all over the place, and one cannot help wondering almost immediately, upon inspecting a design like that, what sort of a repair bill the manufacturer who installed it would have after the first twelve months' working.

Sir Arthur Duckham has referred to the fact that, so far, tunnel kilns have been used to only a very small extent in the burning of refractories. I think, in America, there are one or two tunnel kilns in use for this purpose. There have also been one or two in Germany. I am not quite sure about France, but so far as I know the only tunnel kilns which are actually at work at the present time burning refractories are slight modifications of the original Faugeron kiln, which many of you have seen at various times on the Continent, and so far as I have been able to ascertain from looking through specifications and written descriptions of these kilns, the only difference between them has been the particular method or application they have employed in order to improve and make more perfect the circulation in the tunnel itself. The method shown on the drawings by Sir Arthur Duckham seems to me a very simple one and it certainly has the added advantage that it reduces the length of the structure very considerably, whilst it still gives you that proportionate travel of the gases which is what you really want to get.

I said earlier on that the perfect kiln has not yet been designed. With all due respect to Sir Arthur Duckham I think that possibly that statement may still be true. But I do want to say this: that whether that statement is true or not, a more perfect kiln than those which we already have at our disposal is absolutely essential if this industry of ours in its various branches—silica, firebrick or whatnot else—is going to meet the demands that are being made more and more insistently upon it. You have heard some of those

demands referred to this morning by several of the coke-oven managers. Now it stands to reason that the refractories employed in the construction of furnaces must keep pace with the gradually increasing temperatures at which these furnaces are having to be worked. One way of meeting this will be to ensure that there is no appreciable movement of the structure after it has been erected. You cannot absolutely eliminate that, of course, but you can very nearly if the material is properly burnt, and I am convinced, from a good many years' experience as a maker of refractories, that one essential thing for turning out a successful brick, which shall stand up to the severe demands that are made upon it in industrial furnaces of the present-day and of the future, is proper burning.

As I have said before, you can spend any amount of money on the raw material, its preparation and its working, but if it is not dealt with properly in the firing, if the heat treatment is not properly applied and properly carried out to completion, you will throw away all the trouble and labour that you have displayed in the earlier stages and the results will not be satisfactory either to the user or the maker of the material. I hope the lead that has been given by Sir Arthur Duckham in his paper to-day will be followed up. I could say quite a lot on the importance of it, but enough has been said by Sir Arthur to make it abundantly evident that it is a point to which we have got to pay very particular attention in the future. Again I would urge upon all connected with the refractory materials industry to back up the research work that is being prosecuted into such questions as these. I sincerely hope that we shall all bear the matter specially in mind.

XXIII.—Black and Grey Flints.

By A. Heath and A. Leese.

A short time ago, we were able to show the results produced by varying the temperature of calcination of a given type of flint (Trans., **20**, 121, 1921). The object of the present paper is to call attention to the effect produced by varying the kind of flint. The idea was suggested by the knowledge that much trouble had been caused by a certain fault, which, for want of a better name, has been called "chittering." We are informed by a certain manufacturer, that this fault has cost him thousands of pounds during the last few years. In appearance, this fault closely resembles "dunting," but, unlike dunting, it does not always appear immediately after the ware is drawn from the glost oven, but is liable to occur on the ware subsequent to decoration, or even on white ware which has been stored in the warehouse. The fault had been attributed to the use of grey flints, and it was consequently considered necessary to test thoroughly this hypothesis. Accordingly, some grey flints and also some black flints were selected and calcined at the same temperature, in separate saggars.

It was first noticed that the grey flint shattered much more readily than the black; the latter retained its original shape fairly well, whilst the grey became quite crumbly and much more powdered. In pounding them for grinding, it was also found that, whereas the black required considerable force to bring it to the required size, the grey was very easily crushed. This observation was subsequently confirmed by Mr. Kirkby, who adds that the black also gives a much thinner slip in the same weight per pint than the grey. Each variety was ground in a cylinder and the fineness was as near as possible the same, both easily passing 160's-lawn with approximately 1 per cent. residue.

The specific gravity of the flints was carefully ascertained, with the following results:—

Grey	2·471
Black	2·467

This was taken from an average of a whole saggar of each. It was thought that the variation, although only ·004, might be caused by one saggar being placed above the other. A smaller trial was therefore made by taking some of each and calcining it in four small cups placed alternately thus: $\begin{matrix} \text{B} & \\ \text{G} & \text{G} \\ & \text{B} \end{matrix}$, the whole four occupying a very small space and all touching each other. Each pair was ground together, and the resulting figures for sp. gr. corresponded, within ·001, with those given above.

A quantity of a standard earthenware body was then made into plates, which were fired, biscuit and glost, in the same saggar. All came out of the biscuit and glost oven in good condition, with the exception of a few that were broken, apparently owing to strains while in the clay state.

The glost-fired plates were allowed to stand for two or three weeks, and it was then found that one of the grey flint bodies had developed the fault under discussion.

Five plates of each variety were finally submitted to tests by Mr. A. G. Richardson. The tests consisted of applying smart taps to the plates with a sorting tool. If the plate split easily, it was assumed that the fault would be likely to occur. As a result of this test it was found that four of the five grey flint bodies gave way, while the five black remained intact, although, in all probability, they actually received more severe handling than the grey.

DISCUSSION.

Mr. A. G. Richardson:—I must apologise for attempting to make before a scientific society a test which, to my mind, is very crude. Ever since the Society was started we have been attempting to reach scientific standards. This particular test is far from scientific; it is like going a long way back. It is an unscientific test because it is not under control. But Mr. Heath suggested that by testing these plates in this way we might have some indication of certain faults or some indication that the body had something in it which was not quite satisfactory. Mr. Heath suggested that I should make these tests, because he knows that in years gone by, when certain faults have cropped up, I have tested them by this particular method, and the fault has always been indicated in this very simple manner, viz.:—by testing with the sorting tool. When I was associated with the pottery classes, I had quite a number of students who brought samples which showed these troubles. I have also met with them myself, so that the test and the result have been based upon a certain amount of practice.

Now, what particular causes have brought about the result of splintering which Mr. Heath has referred to as "chittering"? One of the faults I found was the use of grey flints. We had been in the habit of using black flints, when, quite suddenly, a certain type of dunting developed such as we had not been in the habit of experiencing. I consulted various people who had had more experience of flint milling than I had myself at the time, and they did not quite understand what was happening or what had happened. So we worked together, and we began to make certain tests on lines similar to those which Mr. Heath has described, viz.:—by calcining various flints, grey and black together, in saggars in the oven. We found that the greyish type of flints always splintered very finely, whereas the black flints always kept

their shape. We followed that up, not upon such a small scale as Mr. Heath has referred to, but on a large scale, by grinding a batch of grey flints and making a proper body mixture, and repeating this, but using black flints. We then fired these together in the same biscuit saggar and the same saggar in the glost oven, and applied a test as follows: When the sorter in the sorting warehouse tapped certain articles with the sorting tool they were split; a chamber being sorted would split across the bottom. This suggested the idea: If a sorter splits the article in the ordinary way of working, it is necessary to provide a body which will withstand the action of the sorting tool without splitting. So we decided to apply the same test that the sorter applies, viz.:—sharp tapping. By tapping with the sorting tool, without even looking to see which was which, we invariably found the same result, *i.e.*, that the grey flints, made up into flat or chambers, and treated in the way I have described with the sorting tool, would always splinter, whilst those made from black flints never did. That was the result of practical experience. Since then I have been associated with tests that have been made on a smaller scale and on every occasion, when I have had anything to do with such a test, the same result has been obtained.

Mr. Heath has now made these tests and he brought some plates to me the other day which I tested, with the results that he has given you.

While referring to grey flints developing this dunting fault, I would like to say that this is not the only cause of this particular trouble. From practical experience I have found that, by mixing up bodies with overground flint, I have got precisely the same result. I have found also that other people, by using mild stone to displace hard purple stone, have got the same result. I do not think there are any other factors that have come to my notice as causing the fault. The four main faults are, as I have given them to you: (1) grey flints; (2) overground flint; (3) excess of flint; and (4) displacing hard purple stone by mild stone in the body. I have seen this proved more than once by this particular test, whereas articles made at the same time and fired in the same saggar have not developed the fault. That is why I agreed to perform this test to-night. I did not want to do so because, as I have already said, it is not a scientific test, and we ought to have some better method of testing. But having employed this method, and having been able to prove certain points by it, I agreed to perform the test publicly to-night. I would like you to bear in mind that I am not performing this test to prove anything at all. I simply want to make a test as nearly as possible to tests I have made before many times.

Mr. H. E. Wood:—Those of you who have done any work on this subject will agree with me that this fault is likely to happen if you use grey flints. If you will use grey flints, either wholly

or in excess, you will have your ware liable to this particular fault. Whether you give the plates sharp taps with the sorting tool or allow the fault to develop naturally, is only a matter of difference of time. The test which Mr. Richardson has employed seems to show the fault, although, as he says, it is a very crude test. I do not know whether it is possible to invent a really good test. If any of you have thought of one, I have no doubt that Mr. Heath and Mr. Richardson will be greatly obliged if you will give the meeting the benefit of your advice. And I am sure Mr. Heath will be willing to submit his samples to any test you may advise.

XXIV.—Note on the Abrasion of Fireclay Materials.

By Walter C. Hancock, B.A. (Cantab.), F.I.C., and W. E. King, A.R.C.S., D.I.C., A.I.C.

THERE is comparatively little information available on the subject of abrasion of fireclay materials. Although cases of actual rubbing down of the surface do not occur often, still, the determination of such action may be useful at times as a method of comparing the power of resistance to erosion of different surfaces. In the present paper, attention is confined to the simple rubbing away of a surface and not to erosion by impingement of a stream of particles, *e.g.*, fuel ash, etc.

The chief methods that have been used for the determination of abrasion are :—

(1). The Bauschinger Grinding Machine.
(2). The "Wearing" test.
(3). The "Rattler" test.

The first machine consists of a horizontal rotating disc which is dusted with a known weight of emery powder of standard grade. A weighed test-piece, in the form of a half brick, is held in contact with the disc and after a known number of revolutions of the latter, is again weighed. This operation is repeated several times, the number of revolutions of the disc being increased each time. A measure of the amount of abrasion is obtained by dividing the total weight of the material lost during the experiment by the specific gravity (by volume) of the test-piece.

The second method consists in determining the loss of weight of a test-piece caused by the action of a sand-blast, as described by Bradshaw and Emery in Trans., **19**, 79, 1920.

The specification for the "Rattler" test, as given by the National Paving Brick Manufacturers' Association of America, is as follows :—"By revolving the brick or material in a barrel, with a definite number of wrought-iron balls of prescribed size and chemical composition, at a fixed rate, for a given number of revolutions, and calculating the percentage weight of the loss by abrasion." Minute details of the construction of the machine are given by the Association, together with the limits of chemical composition of the iron spheres. The test-pieces are to be within certain dimensions and cleaned and dried, for at least three hours, at a temperature of 100°C. before testing. (See also, Havard, *Refractories and Furnaces*, p. 260).

It is obvious that in the above methods, abrasion is caused not by direct rubbing but rather by grinding, and further, that experiments can only be carried out within a strictly limited range of

temperature. With these points in view, we adopted a different method of testing.

The apparatus we used consisted of a long metal arm, jointed in the middle, one end of which was attached to an eccentric, driven by an electric motor. The other end was fitted with a small metal clamp to hold the test-piece. The metal rod passed through two series of guides, one on either side of the joint, so as to ensure a steady horizontal movement. The apparatus was arranged so that the test-piece in the clamp was moved backwards and forwards over the surface of another block, which might be of the same or different material, and was kept fixed, so that really the mutual abrasion between two surfaces was determined. The eccentric was adjusted so that the "throw" on each side of the central position was equal. (See Figs. 1 and 2.)

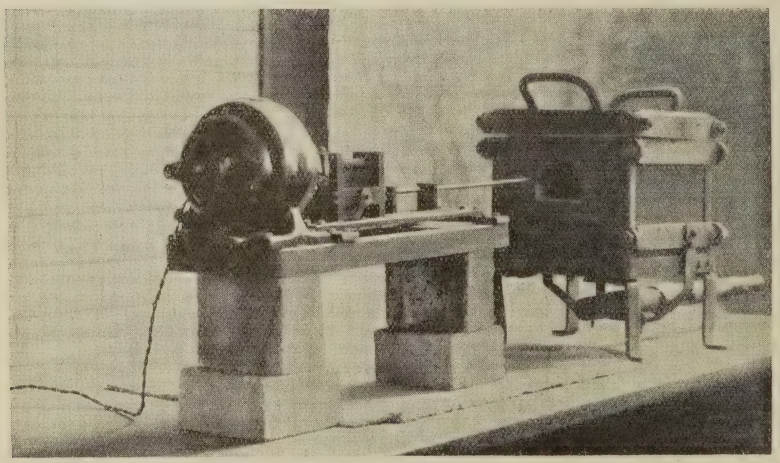


Fig. 1.

The test-pieces were carefully dusted with a fine brush before and after each test, to ensure that all abraded particles were removed, and the percentage loss of weight was taken as a measure of the amount of abrasion. When this loss is very small it is convenient to reckon the "loss per 10,000 strokes." It was found that when fresh surfaces of the test-pieces were used a higher value was obtained during the first hour, due to accidental irregularities on the surface; consequently all surfaces were subjected to abrasion for an hour before the actual determinations were made.

The method has the following advantages:—(1) the wear is caused by actual abrasion, and not by grinding or scouring; (2) by loading the moving arm the pressure of abrading surfaces can be increased; (3) the abrading action of different materials on the test-piece can

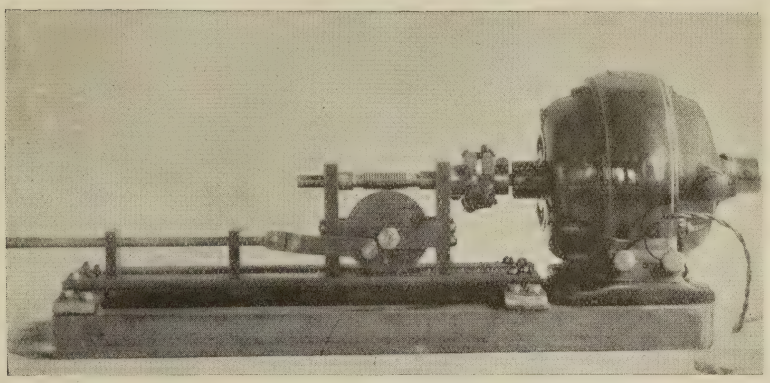


Fig. 2.

be determined by substituting various materials for the upper abrading surface; (4) by placing the machine in such a position that the fixed and moving test-pieces are within a furnace, the abrading action at high temperatures can actually be determined.

A great many experiments were made to investigate the influence of the following factors: (1) increase of temperature; (2) variation in texture of surfaces and (3) load, but only a few general conclusions can be mentioned here.

A few preliminary experiments were made on two pairs of bricks to test the apparatus, with the following results :—

	Duration of Test in hours.			
	1	3	8	18
Percentage loss of upper brick ..	0·16	0·33		
,, ,, lower ,, ..	0·14	0·32		
Percentage loss of upper brick ..	0·11	0·19	0·26	0·50
,, ,, lower ,, ..	0·11	0·18	0·26	0·51

From the above results, it appears that when the two test-pieces are of the same composition, the amount of abrasion is about the same for each.

Some experiments made at high temperatures on test-pieces of the same composition, *i.e.*, neat clay, gave the following results for a test of one hour's duration :—

Temperature	Percentage loss of weight
20°C	0·13
950°C	0·87
1050°C	0·75

The following curves (Fig. 3) show these results and also, for comparison, the abrasion of neat clay at 950°C.

The increase of abrasion with rise of temperature is also seen

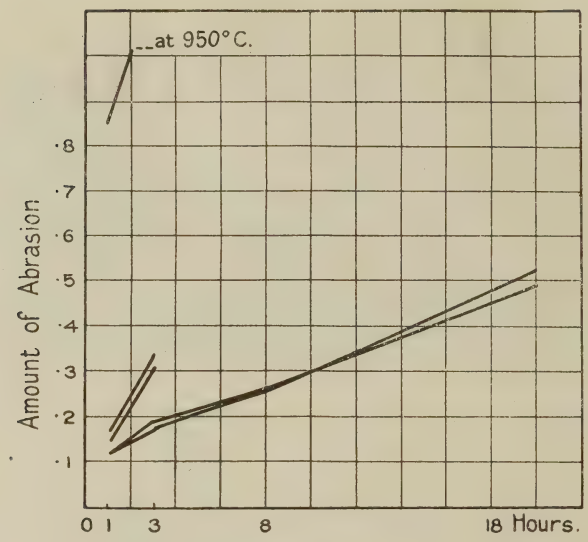


Fig. 3.

in the following case of test-pieces, composed of 60 per cent. of clay and 40 per cent. of grog (passed a $\frac{1}{16}$th inch and retained on a 30-mesh), in a test of one hour's duration :—

Temperature	Percentage loss of weight
20°C	0·115
1050°C	0·255

These results indicate that abrasion certainly appears to be more pronounced at high temperatures.

The following table shows the proportional amounts of abrasion when the two rubbing surfaces had the same texture. All our experiments were made with small laboratory test-pieces composed of Stourbridge fireclay, and the same clay, hard fired, as grog. The various mixtures were :—

(1).	Neat Clay.	
(2).	Clay, 80%;	Fine grog 20%.
(3).	,, 80%;	Coarse grog 20%.
(4).	,, 60%;	Fine grog 40%.
(5).	,, 60%;	Coarse grog 40%.

The "Fine grog" passed $\frac{1}{16}$th inch, and was retained on a 30-mesh, and the "Coarse grog" passed $\frac{1}{8}$th and was retained on $\frac{1}{16}$ inch.

Neat clay abrading neat clay	..	1·0
Mixture 2	,,	Mixture 2	..	1·3
,, 3	,,	,, 3	..	1·3
,, 4	,,	,, 4	..	2·0
,, 5	,,	,, 4	..	2·6

The mutual abrasion between a neat clay test-piece on the one

hand and test-pieces of the above composition on the other is shown below, the amounts being expressed as ratios :—

Neat clay.	Mixture 2	Mixture 3.	Mixture 4.	Mixture 5.
1·0	1·0	1·0	4·0	3·0

Except for the last figure in this table, all the results indicate that the amount of abrasion tends to increase as the coarseness of the texture increases—the increased coarseness being due either to the amount or to the larger grade of the grog.

In all the experiments recorded up to this point, the pressure on the abraded surface was that due to the test-piece and clamp, about 140 grams. A set of determinations was made to see the effect of added loads of 100 and 500 grams on neat clay blocks fired at 1,000°C., and the results, expressed as percentage losses of weight, are shown in the following curve (Fig. 4).

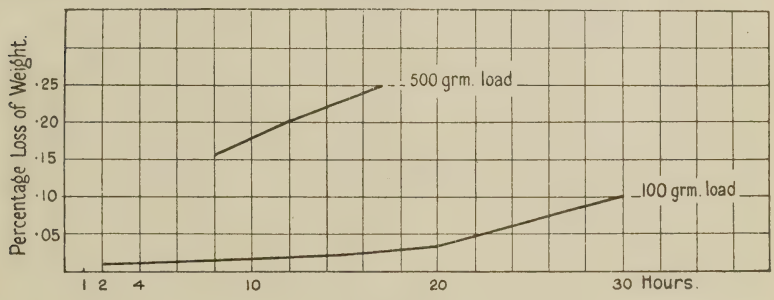


Fig. 4.

Further experiments were made on some test-pieces, composed of clay and ganister that had been fired at 1,200°C., and the results are shown in the next curve (Fig. 5). With no load on the arm the loss due to abrasion was negligible.

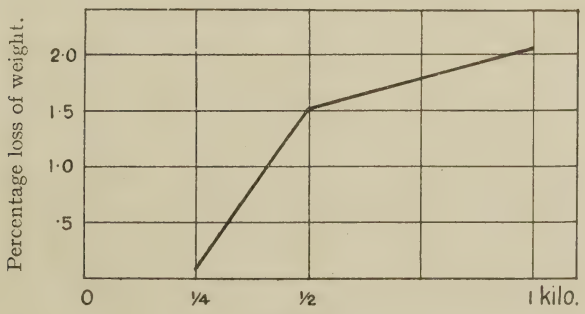


Fig. 5.

With regard to the influence of temperature of firing on the amount of abrasion, it was found that specimens, fired at 1,000°C.

showed a percentage loss of weight of 0·324 per 10,000 strokes, whereas others fired at 1,200°C. only showed a loss of 0·015 under the same conditions.

Summary. The general conclusions arrived at from the experiments confirm what would be expected, namely:—

(1). Fine-grained firebricks resist abrasion more than those of coarser grain, and the admixture of grog, both as regards size of grain and quantity, decreases resistance to abrasion.
(2). Abrasion appears to increase at higher temperatures.
(3). Hard firing of the bricks tends to decrease abrasion.
(4). Increase of abrasion is caused by the addition of load to the wearing surfaces.

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XXV.—Dolomite.

By L. M. Parsons, D.Sc., D.I.C., F.G.S.

THE mineral substance known as dolomite was first described by the mineralogist Dolomieu, in 1781, when he drew attention to the nature of certain calcareous rocks of the Tyrol. Since that time much study has been devoted to the properties and origin of this mineral, and though these studies have been mainly of academic interest, I propose to consider, in this short paper, certain general principles, and a few facts which may be of some value to those interested in the economic uses of dolomite either as a refractory material, or as a source of magnesium.

Dolomite is one of those minerals which frequently occur on a scale large enough to form a rock in itself, and in this extensive mode of occurrence it is usually a bedded substance very like ordinary limestone with which it is closely related. In fact, most extensive dolomites are produced by the alteration of rocks originally deposited as normal limestones. It is not always easy to identify dolomite in hand specimens or in the field. Usually it is a stony substance having a pale yellow colour, but it may be of a light gray tint, when it is very difficult to distinguish it from limestone. At other times it is much darker, closely resembling in appearance a dark sandstone. Occasionally it is tinted bright red by the presence of iron oxide. Sometimes it is very compact, at other times porous and friable. Sometimes quite a small area may afford examples of all of these varieties, the district a little to the north of the Leicestershire Coalfield, for instance. Some dolomites are quite barren of fossils, while others contain numerous organic remains, such as corals, shells, etc., exhibiting various stages of alteration, depending partly on the mode of dolomitisation and, to some extent, on the original composition and texture of the rock.

Chemically, dolomite is a double carbonate of calcium and magnesium, and must not be confused with a mere mixture of these carbonates, such mixtures being known as magnesian limestones. Hence calcareous rocks containing magnesium are of two distinct classes—magnesian limestones, having a very variable proportion of magnesium carbonate, and true dolomite, a double salt consisting of these carbonates chemically combined in a definite proportion indicated by the molecular weight. If the formulæ for these substances are given, it may help to make this difference clear. The formula for a magnesian limestone is written $CaCO_3+MgCO_3$, and the proportion of magnesium carbonate may be anything from 1 to over 40 per cent., whereas the formula for dolomite is $CaMg(CO_3)_2$, and the proportion of magnesium carbonate is always 45%. Of course this proportion is true for a perfectly pure dolomite, but such

pure dolomites are rarely found on a scale sufficiently large to be of economic value. Most extensive dolomites contain a small proportion of free (uncombined) calcium carbonate or calcite, intimately mixed with the dolomite. As a rule, a magnesium limestone contains, here and there, crystals, veins, streaks, and patches of fairly pure dolomite, but this patchy "vein dolomitisation," as it is termed, is not of much use economically.

Magnesian limestones being very variable in their magnesian content, and "vein" dolomites being on too small a scale for commercial purposes, we must rely upon those extensive dolomites which contain a high proportion of magnesium.

The best rocks are those dolomites which fulfil, as far as possible, the following conditions:—

(1). The dolomitisation should be sufficiently extensive to warrant a large supply of material.

(2). The proportion of magnesium carbonate should be high, as near the 45% of a theoretically pure dolomite as possible.

(3). The chemical composition should be fairly constant over areas sufficiently large. In other words, patchy dolomitisation is undesirable.

(4). The rock should be of compact and uniform texture, loose dolomites which weather to "dolomitic sand" being of less value than the tougher compact varieties.

From these practical considerations several questions naturally present themselves. How are such dolomites produced? How are they recognised? Where do they exist on a large scale? And so on.

Now there is, in general, some relation between the modes of origin of dolomite and the presence of characters which fulfil the conditions stated above. This being the case, these practical questions are, perhaps, best answered by a brief consideration of the types of dolomite produced by various modes of formation. Stated very broadly it may be said that there are two distinct groups of dolomitic rocks, Primary and Secondary.

The Primary group includes those dolomites which are produced, either chemically or mechanically, in the dolomitic state originally, and are not formed by chemical alteration of rocks first existing as normal limestones.

The Secondary group includes those dolomites formed by the chemical alteration of rocks originally deposited as ordinary limestones, such alteration being brought about, in most cases, by the influence of water containing magnesium salts in solution, and in much rarer cases, by heated vapours containing magnesian substances.

Of the primary dolomites, two types are of interest:—

Precipitated dolomites. (Proto-dolomites). Old salt-lake waters heavily charged with calcium and magnesium salts, would, by evaporation, precipitate such minerals as gypsum and dolomite

in addition to rock salt and other chlorides. These precipitates would be remarkably uniform in character, and as far as dolomite is concerned, the proportion of magnesium would remain high. The water of such lakes would be very unsuitable for living creatures, hence minerals deposited in this way contain very few fossils. It is obvious that dolomites produced in this way are excellent for practical purposes, but, unfortunately this type of rock is not represented in our own country. The Permian magnesian limestone (not a true dolomite) which extends from Durham to S.E. Nottinghamshire is of similar origin, but the magnesian contents are very variable, true dolomite being scattered through it irregularly as occasional nests, patches, veins, etc. Some larger masses of dolomite are of local occurrence as at Warmsworth, near Doncaster, and the material of such masses approaches in composition that of a pure dolomite.

Mechanically-formed Dolomitic Sediments. Where old dolomitic rocks were being subjected to prolonged weathering and river action, particles of these rocks would be washed down to the sea where they would collect to build a new dolomitic rock of a fragmental kind. Such dolomites are rare in this country, and are more or less local in extent. Examples occur in S. Wales. But apart from their local extent, other factors may prevent their being of economic importance. Some fragmental dolomites consist of dolomitic lumps cemented together by a matrix of non-dolomitic nature, while in other cases, the Dolomitic conglomerate of the S.W. of England, for instance, the matrix is the dolomitic part. In these types the dolomitisation is partial. For most commercial purposes we have to rely upon the dolomites of secondary origin.

The Formation of Secondary Dolomites. A normal limestone consists of shells, corals, crinoids, and other organic fragments which originally collected on the sea floor, but have since been cemented together to form a compact rock now raised above the sea level. The cementing material is frequently a finer calcareous mud, but it may contain a small proportion of sand, clay, or iron oxides. Calcareous matter including organic structures and matrix forms the bulk of the rock, and any or all of this calcareous matter may be altered to dolomite when it meets with waters containing magnesium salts in solution. There are two distinct modes by which this alteration may be brought about. The original sea in which the limestone was first deposited may contain sufficient magnesium salts to cause a chemical reaction between these salts and the calcareous accumulation lying on the sea floor. In other words, the alteration to dolomite occurs *before the limestone becomes land*, hence dolomites of this origin are described as *contemporaneous*. Considerable information concerning this mode of dolomitisation has been obtained in recent times from borings sunk through coral reefs. Coral structures have been found in various stages of dolomitic alteration, and certain algae have been

found instrumental in the production of dolomite.

The other mode of Secondary dolomitisation consists of alteration due to ground waters containing magnesium salts percolating through limestones forming part of the land. Since this dolomite was formed long after the rock was originally deposited as an ordinary limestone it is termed *subsequent*. In many cases the magnesian ground waters have affected a limestone merely here and there, so that the dolomite produced is in veins, streaks, and patches. But alteration by ground waters may proceed over a long period and eventually produce a completely dolomitised mass of considerable thickness and extending over a large area. Hence the classes of dolomite which are of most use commercially are those of the contemporaneous class, and those resulting from extensive, long continued, and fairly complete subsequent alteration of a limestone district. This being the case, perhaps a brief outline of some characteristics of these two types of rock may be of some use.

Contemporaneous Dolomites. Rocks of this class exhibit such features, as one would expect from a process of alteration due to a solution which may operate uniformly over a wide area, the existing conditions being practically the same at one place as at another, perhaps some miles distant. The chief features which a geologist expects to find in a contemporaneous dolomite are:—

(1). The dolomite persists along certain beds of rock, and if an unaltered limestone is seen above or below the dolomite, the two kinds of rock are sharply separated by the bedding planes. In other words, this kind of dolomitisation is characteristic of certain levels (horizons) in the formation.

(2). The dolomitisation extends for long distances, usually several miles, and the change to ordinary limestone, if seen, is found to be gradual, not abrupt. Hence patches of dolomite alternating with masses of limestone are not characteristic.

(3). The chemical composition and texture are fairly uniform over wide areas.

(4). Thin sections with a microscope show that the material is either a fine mosaic of dolomite grains of irregular shape, or a mass of small rhombohedral crystals. Where the dolomitisation is more complete the mosaic habit is usual.

(5). The crystals and grains are free from iron oxides arranged centrally within the crystals.

(6). There is less tendency to form very porous structures than there is in some subsequent dolomites, hence the contemporaneous varieties are more compact and durable.

(7). When dolomitisation is complete, both fossils and matrix are altered, but where the dolomitisation is not complete the matrix may be more altered than some organic structures, or *vice versa* depending upon the comparative susceptibility of the original matrix and organic structures.

Although dolomitisation may affect calcareous rocks of any geological age, in this country the most extensive examples of contemporaneous types occur in districts where the formation known as the Carboniferous Limestone is exposed. In South Wales, dolomites of the area near Cardiff have been described by T. F. Sibly of University College, Swansea, and F. Dixey.[1] Other interesting dolomitic types found in the Gower Peninsula have been discussed by E. E. L. Dixon, of the Geological Survey.[2] Contemporaneous dolomitisation occurs in the middle portion of the famous Avon section at Clifton, Bristol, where the late A. Vaughan established his well-known series of palæontological zones,[3] and in the middle part of the Burrington Combe section in the Mendips, described by S. H. Reynolds of Bristol University[4]. In the North of England, dolomites of the same class are extensive in the Shap and Ravenstonedale districts, and have been described by E. J. Garwood, who has shown the importance of calcareous algae and coral formations as factors of this kind of dolomitisation.[5]

Some of these rocks exhibit various stages of incomplete dolomitisation, particularly some of the mottled dolomites, called "Pseudo-breccias," described by Dixon. One of the most completely dolomitised rocks of the contemporaneous class occurs in a relatively small area not very distant from your head-quarters at Stoke-on-Trent. North of the Leicestershire Coalfield, between Charnwood Forest and the town of Melbourne (S. Derbyshire) several large masses of dolomite of lower Carboniferous age project through a thin covering of Triassic marls. I have studied the rocks of this district for some years and have given a description of their petrological[6] and palæontological characters, but perhaps I may be excused if I again refer to certain facts in this paper. Several hundred feet of well-bedded yellow and grey dolomite of remarkably uniform composition and texture are exposed at Breedon-on-the Hill and at Breedon Cloud, where there are extensive quarries. The proportion of magnesium carbonate is about 40% and porous structures are not common. Microscopic sections show that the material is composed of a very fine grained mosaic of irregular dolomite grains. Organic structures are quite uncommon in the material worked at Breedon and the rock is here correspondingly compact. At Breedon Cloud, higher, more fossiliferous beds are being worked, though fossils are not so numerous as to render the bulk of the material friable. A line of fault acts as an eastern boundary to these dolomitic exposures, this line running southwards towards Charnwood from Melbourne. West of this fault much

[1] *Quart. J. Geol. Soc.*, **73**, 116, 1916, also Sibly, *Proc. Geol. Association*, Vol. xxxi., p. 83.
[2] *Quart. J. Geol. Soc.*, **67**, 507, 1911.
[3] *Quart. J. Geol. Soc.*, **61**, 181, 1905.
[4] *Quart. J. Geol. Soc.*, **67**, 349, 1911.
[5] *Quart J. Geol Soc.*, **68**, 457, 1912
[6] "Dolomitisation and the Leicestershire Dolomites" *Geol. Mag.*, (6) **5**, 246, 1919.

valuable dolomite exists merely covered by a thin mantle of Triassic rocks.

Subsequent Dolomites. In these rocks the production of dolomite has not been brought about by a widespread solution acting uniformly over large areas. The agent of alteration consists of ground waters which, here and there, percolating through limestone masses select such portions of limestone as are more susceptible on account of fineness of grain or other inherent factors. It is obvious that in the earlier stages of such processes a very scattered and patchy dolomitisation is produced; merely veins and patches of dolomite in places. Some altered limestones never advance beyond this early stage. Long continued action by the magnesian waters, spread over several distinct periods perhaps, will lead to a more thoroughly dolomitised rock, which may resemble in several ways a completely altered dolomite of contemporaneous or even primary origin. In the Carboniferous Limestone districts mentioned above, and in other areas such as Northern Derbyshire, a certain amount of the incomplete "vein" dolomitisation is present, though its development may be very restricted. A district that has afforded a type example of subsequent dolomitisation and described by Professor W. W. Watts,[7] is the Carboniferous Limestone area near Abergavenny.

Except in very advanced stages of alteration, when the whole rock is dolomitised, the characteristic features exhibited by this class of dolomite include:—

(1). The dolomitisation is not necessarily confined to any particular beds or strata, but passes up or down from one bed to another.

(2). There is a general lack of persistence along any beds. Sooner or later the dolomite is seen to pass abruptly into ordinary limestone. Hence masses of dolomite alternate with masses of limestone.

(3). A mass of dolomite frequently sends out veins or epiphyses of dolomite into the surrounding limestone.

(4). The chemical composition and texture are varied even within a small area.

(5). Microscopic sections show either a coarse mosaic of irregular dolomite grains, or as is more frequently the case, large rhombohedral crystals often containing iron oxides or other impurities arranged centrally within the crystals.

(6). There is a marked tendency to form porous structures even on a scale large enough to be seen by the unaided eye.

(7). Fossils may sometimes be dolomitised before the matrix, but this feature is not always a sure guide in diagnosis.

(8). There is a tendency to weather into fantastic and castellated masses as in Central Derbyshire.

Extensive examples of dolomite of subsequent type in a very

[7] Geology of Abergavenny (*Mem. Geol. Survey*).

advanced stage of alteration are not common. The best example in this country is probably the Carboniferous Limestone area a little west of Wirksworth in Central Derbyshire. Here there are several miles of moorland composed of a dark grey rock which contrasts strongly with the light coloured limestones below and above. So complete is the dolomitisation that one would, without careful study, conclude that these rocks were bedded dolomites of the contemporaneous class. The alteration is most thorough in the mass known as the Harboro' Rocks, and from that place outwards in all directions the proportion of magnesium carbonate decreases.[8] The Harboro' specimens yield about 38 to 40% of magnesium carbonate. Examined with a microscope the material is seen to consist of a mosaic of irregular grains, thus contrasting with subsequent dolomites of many other areas where the alteration is less complete. There is considerable development of porous structures so that the weathered surfaces of the rock have a characteristically pitted surface. Much of this material which passes Westwards towards Alsop-en-le-dale is unworked, but I understand that since my examination in 1918 and 1919 a company has decided to work the dolomite near the Harboro' Rocks.

Dolomites of a more complex type in which ground waters have further altered rocks partly dolomitised by the contemporaneous process exist in some of the Carboniferous areas, but as yet they have not been studied in detail. Much may yet be done in this respect. In conclusion I must express the hope that although my own investigations have been mainly of a purely scientific kind, there may be in this brief outline of the subject some comments which are of a little value to those interested more in the economic aspects of dolomite.

Explanation of Figures.

Figures 1 to 3 are section diagrams representing the modes of formation of Secondary Dolomites.

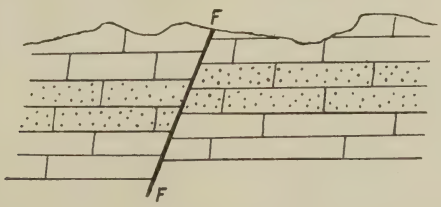


Fig. 1.

Fig. 1. Illustrates the mode of occurrence of a Contemporaneous dolomite. The dolomitisation is confined to certain beds or horizons and the fault has not been a factor of dolomitisation. Dolomitic epiphyses do not occur.

[8] *Geol. Mag.*, **59**, 113, 1922.

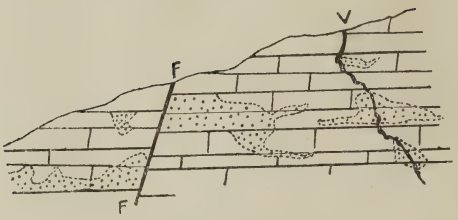


Fig. 2.

Fig. 2. Represents "Vein" dolomitisation, or subsequent alteration along faults (FF), veins (V), or bedding planes. Dolomitisation attacks susceptible portions of rock irrespective of bedding.

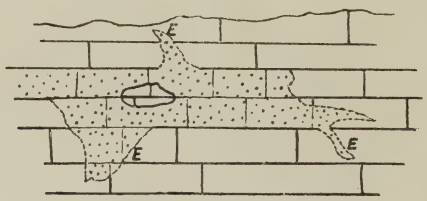


Fig. 3.

Fig. 3. Shows subsequent dolomitisation which selects certain more susceptible portions of limestone. In this case faults and veins are not instrumental. Dolomitic epiphyses (E) or offshoots, and a remnant of limestone are shown. On the whole certain beds are more susceptible to alteration than others.

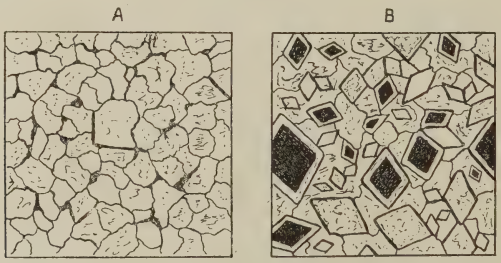


Fig. 4.

Fig. 4. Illustrates the microscopic appearance of certain dolomite types, as seen in thin sections. *A*. shows the granular mosaic habit assumed by dolomite in most rocks of the Contemporaneous class. Few rhombohedral outlines are present, and iron oxide, if present, is interstitial. Intense subsequent dolomitisation may produce a *coarse* mosaic of this type.

Fig. 4. *B*. Shows the characteristic appearances assumed by most dolomites of the subsequent class. Rhombohedral crystals appear, sometimes clear, and in other cases containing zonal growths of iron oxide. Some complex dolomites show both of these structures in the same rock, though more often the crystals will all be clear, or all contain zonal inclusions.

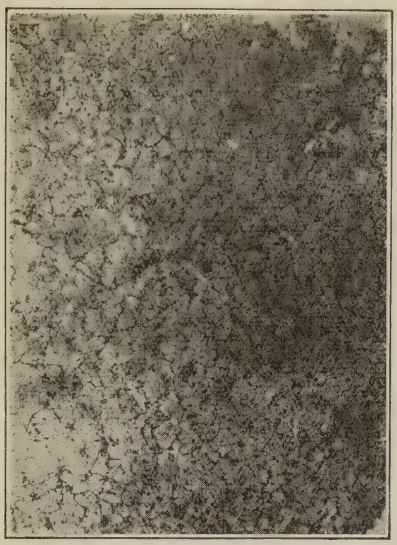


Fig. 5.

Fig. 5. (cf. Fig. 4a) Fine-grained dolomitic mosaic, rhombohedral outlines rare. Contemporaneous dolomite of Breedon, Leicester.

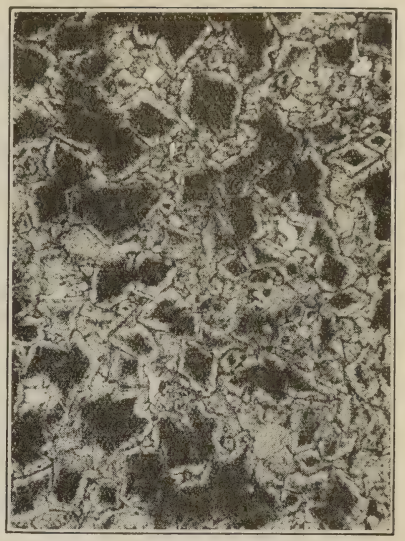


Fig. 6.

Fig. 6. (cf. Fig. 4b). Red dolomite, Breedon, Leicester. Zonal inclusions of haematite are present.

Fig. 7.

Fig. 7. Coarse-grained dolomitic mosaic, as in very advanced and complete subsequent dolomitisation. Harboro', Derbyshire. (Compare size of grain with Fig. 5).

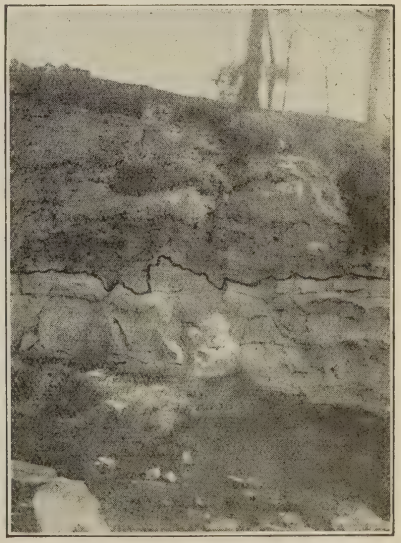


Fig. 8.

Fig. 8. Subsequent dolomitisation, showing failure of dolomite to conform to bedding planes. Dark dolomite above pale grey limestone. (Near Harboro', Derbyshire.

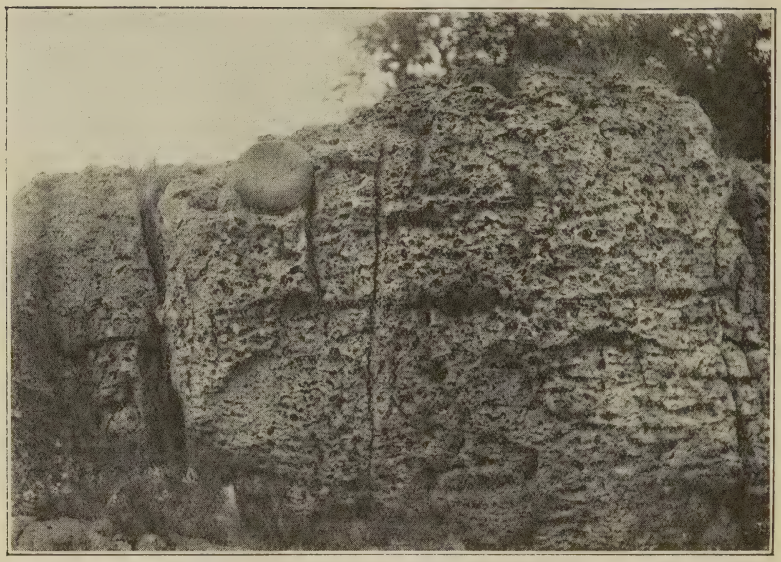


Fig. 9.

Fig. 9. Development of porous structures much more pronounced in subsequent than in contemporaneous dolomites (Near Harboro', Derbyshire).

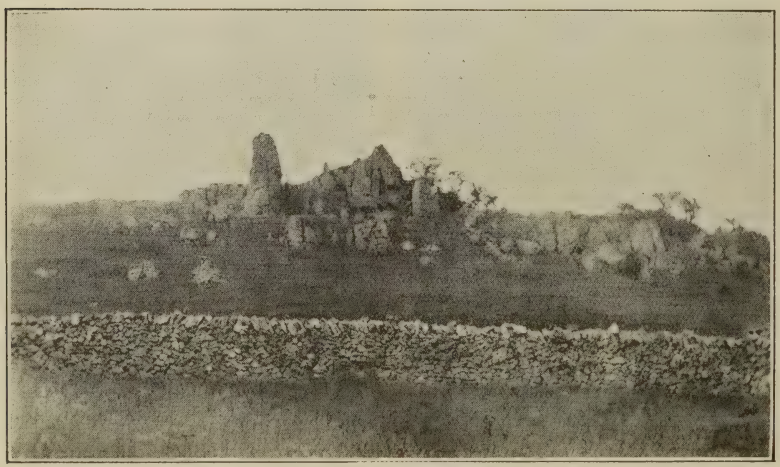


Fig. 10.

Fig. 10. Characteristic weathering of subsequent dolomites, stacks and pillars of dolomite. (Harboro', Derbyshire).

XXVI.—The Physical Properties of Clay.

By S. E. Ackermann, B.Sc. (Engineering), M. Cons. E.

(*Abridged Report.*)

THE Lecturer pointed out the necessity for knowledge of the physical properties of clay in connection with the work of the members of the Ceramic Society, and also with that of engineers.

With reference to the fact that the experiments were on a small scale, it was pointed out that the laws of Nature are true both for the small and the large. The following instances were mentioned: the Law of Gravity, Newton's Laws of Motion, Ohm's Law, Joule's Law, Boyle's Law, and specific instances of experiments with models were mentioned in the matters of wind pressure on model bridges and model aeroplanes; experiments with model ships in Froude tanks; Mr. Crutwell's experiments with model rivers. The lecturer did not suggest that full scale experiments were not necessary, but strongly recommended that small scale experiments should be done first; the experience thus gained would be an invaluable guide for the conducting of the full scale work. He stated that the Whangpoo Conservancy Board had, with the guidance of some of his experiments on model piles, carried out experiments on piles varying from 4 in. sq. and 10 ft. long, to 16 in. sq. by 59 ft. long. These experiments had cost about £8,000, and the six conclusions which the engineers arrived at as a result of this work confirmed six of the lecturer's conclusions previously arrived at by means of the model piles at a cost of one shilling!

The clay with which the whole of the experiments had been made was London clay, obtained from near the surface, which had, consequently, oxidised to a yellow colour. An analysis of London clay was given as:

Silica, SiO_2	57%
Alumina, Al_2O_3	19
Ferric oxide, Fe_2O_3	5
Burnt Lime, CaO	4
Sundries	6
Combined water	9
	100

Reference was made to the colloidal content of clay, which played so important a part in connection with its plasticity,

and it was mentioned that, with regard to the Israelites' complaint that they could not make bricks without straw in Egypt, it had been suggested that the use of the straw was probably not for the purpose of mechanically holding the bricks together (for, if the clay was so weak as to need this, the additional strength due to the strength of the straw would be small), but that probably the straw was needed to produce a liquor by decomposition, which liquor, on being mixed with the clay, would increase its plasticity.

To indicate the fineness of the particles of clay the following figures were given, it being stated that a material was not considered a clay unless the particles were less than 0·002 mm. in diameter.

The total surface of the particles contained in 1 gram of :—

Coarse sand	590 sq. cms.
Loams	1190 ,,
Clays	4200 ,,

The apparatus by means of which the piles and other bodies used for the experiments were caused to penetrate the clay gradually, was described, the main principle of it being that the guide-load-rod was supported in a vertical position by passing it through a hole in a plank. The upper end of the guide-load-rod was rounded, and the load carrier had a cup which was supported by the spherical end of the guide-load-rod, so that the combination formed a ball and socket joint, thus insuring that the vertical line of action of the load was coincident with the vertical axis of the guide-load-rod. The pile or other bodies to be pressed into the clay were rigidly fixed to the lower end of the guide-load-rod.

The three principal sets of experiments were :

(*a*) Square pyramids forced in point downwards.
(*b*) Piles of various cross-sections, some pointed, and some square (or blunt) ended.
(*c*) Discs.

On plotting curves with the loads as ordinates and the penetrations of the square pyramids as abscissae, a series of parabolic curves was obtained, each parabola being for a given percentage of water contained in the clay, this percentage of water being calculated from the amount of water lost on drying the clay for a couple of days at a temperature of 180°F. The experiments with the square pyramids of two largely different vertical angles showed that when the load was divided by the area of the surface of contact between the clay and the pyramid, the result was a constant for any given pyramid and percentage of water in the clay. This, the lecturer had since found, corresponded exactly with the results obtained by Foeppl, who used a blunt-pointed cone, and caused this to penetrate into various metals.

The penetration of a square pyramid into the clay formed a square hole at the surface of the clay, and if the side of this square were b mm. long, then the following relation was obtained for clay

containing 30 per cent. of water, the large pyramid having an angle at the vertex of $37\frac{1}{2}°$.

$b=2{\cdot}22E^{\frac{1}{3}}$ where E = the work done in cm. kilos. in causing the penetration.

Edwards and Willis found for metals $d=CE^{\frac{1}{3}}$, and for tin in particular, $d=2{\cdot}186\ E^{\frac{1}{3}}$ where d was the diam. in mm. of the indentation caused by a 10 mm. diam. ball attached to a weight and dropped on to the metal, and E was the energy of the blow in pnd.-ins. Thus it was seen that there was a close relationship between the law of penetration of bodies into clay and into metals. It was stated that the work done per cubic cm. of clay displaced was constant for any one particular pyramid, or pile, and condition of the clay. Martel found the same result for metals by impact experiments.

The connection between the tensile strength of London clay and its water content was given as follows:

	Tensile Strength.
28% water	80 grms. per sq. cm.
26% ,, ...	140 ,, ,, ,,
24·5% ,, ...	200 ,, ,, ,,
23% ,, ...	300 ,, ,, ,,
5·0%	13,150 ,, ,, ,,

The experiments with the tortional elasticity of a rolled cylindrical specimen of clay containing 28 per cent. of water were described. This specimen tapered slightly, the upper end being larger than the lower, the mean diam. being 20 mm. and the length 68 cms. A spline of wood 20 cm. long was attached in a horizontal position to the lower end of the specimen of clay, and it was found that this lower end could be twisted through an angle of 32°, and on release it returned instantly to zero. The experiment was repeated several times; the spline always returned to zero, but it was found that if the lower end of the specimen was twisted more than 32°, then there was a permanent set of an amount equal to the excess of twist over 32°.

A specimen of clay was rolled so as to form a cylinder 23 mm. in diam. when dried, and about 30 mm. long. This was finally dried at a temp. of about 180°F., and was supported freely at its ends in a horizontal position, the clear span being 25 cms. It was gradually loaded at the centre and did not break until this load was 14·87 kilos. Thus f in the formula $B=fM$ was no less than 78 kilos. per sq. cm.

The method of determining the shearing strength of clay was described, and the following results were given:

Shearing Strength.

p_n	f	μ	w'%
15·5	20	1·285	26·5
44·0	36·7	0·833	26·5
25	43	1·73	25·0
147·5	112	0·76	25·0
279	152	0·545	25·0
412	217	0·526	25·0

In the table:

p_n = the normal pressure between the surfaces at the shearing plane.

f = shearing strength in grams per sq. cm.

μ = the coefficient of "friction."

w' = percentage of water in the clay.

For clay containing 25 per cent. of water it was found that $\mu = \frac{9.47}{\sqrt{p_n}}$ thus showing that, in the case of clay, the coefficient of friction was not constant, as it was in the case of friction between solid bodies, but decreased as the square root of the pressure between the surfaces increased, in the manner indicated by the above equation.

Contraction of London Clay on Drying.

Water. per cent.	Linear Contraction per cent.
17·5	5·9
21·8	6·0
23·0	8·5
25·4	9·0
29·0	11·0

The next set of experiments was devised for the purpose of ascertaining what proportion of the maximum load placed on a pile was supported by the vertical sides of the pile, and what proportion of the total was supported by the direct vertical reaction of the soil on the point of the pile. For this purpose cylindrical piles were gradually forced into clay of a given consistency, in the usual manner of these experiments, by putting on a certain load, leaving it 10 mins. and then reading the resulting penetration, and so on. On the loads and penetrations being plotted, a parabolic curve was obtained, penetrations being abscissae. Then, with the clay in exactly the same condition, a disc of duralumin of the same diam. as the cylindrical pile was fixed at the end of a rod, and similarly forced into the clay. The early part of the load-penetration curve gave a curve somewhat of the nature of a quadrant of a circle, and then at a certain critical load the disc started to sink into the clay without further additional load until the disc was nearly at the bottom of the container. On plotting the load-penetration curves for these two experiments to the same scale,

the intercept at any particular penetration between the two curves gave the amount of load supported by the skin friction on the vertical sides of the pile, the rest being that supported by the end of the pile. In this way in a particular instance it was found that about 80 per cent. of the load was supported by the side friction and only 20 per cent. by vertical pressure. The critical load, or rather stress, obtained by dividing the critical load by the area of the disc, had been called the pressure of fluidity of the material under test, and it had been found that not only did London clay, with varying quantities of water, exhibit this phenomenon, but that even metals such as lead, lead-tin alloy, tin, aluminium, and copper also had the same characteristic, and it had further been found that, on certain assumptions, there was a rational connection between the ultimate tensile and shearing strengths of a metal and its pressure of fluidity. The relationship was

$p = 3{\cdot}68\,c + 5{\cdot}21\,f$, where p = the pressure of fluidity in kilos per sq. cm.

c = tensile strength in kilos per sq. cm.

f = shearing strength ,, ,, ,,

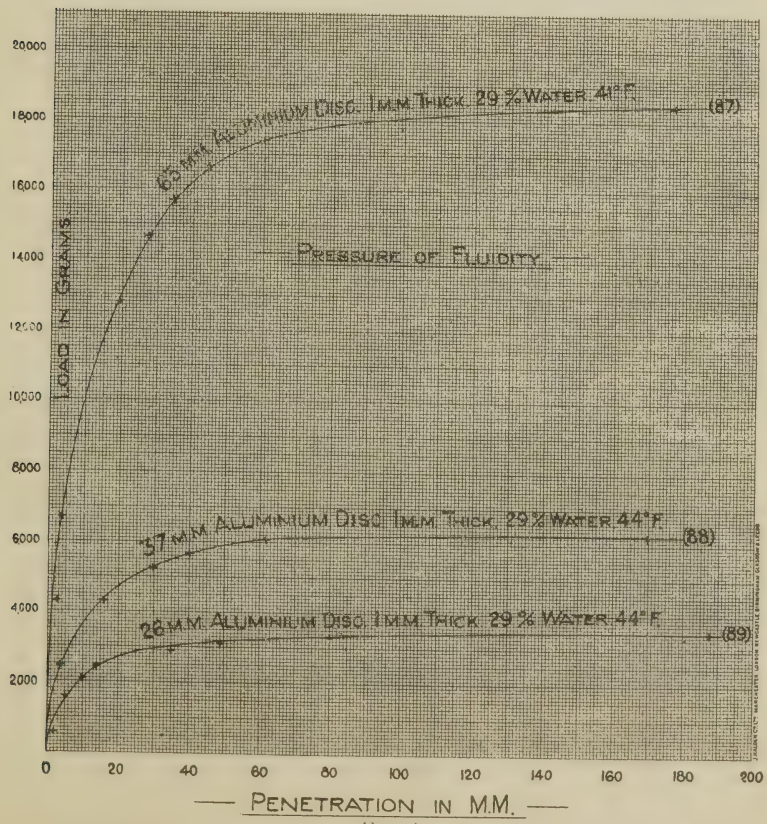


Fig. 1.

In the case of clay the equation was the same, except that the stresses were then in grams per sq. cm. instead of kilos per sq. cm., and in the case of clay the equation gave results more nearly approaching the experimental ones, whereas in the case of metals the equation consistently gave results which had to be reduced by 30 per cent. in order to agree with the experimental values of the pressures of fluidity.

Possibly, if metal specimens much larger than 70 mm. diam. had been used to determine the pressures of fluidity, this 30 per cent. might have been reduced or eliminated.

The lecturer suggested that, as what was called plasticity almost certainly involved among other factors those of tensile and shearing stresses, the pressure of fluidity should be used for comparing the plasticity of different clays, or the same clay containing different percentages of water or other ingredients. To determine the tensile and shearing strengths of clay with accuracy was not particularly easy, but, on the other hand, it was extremely easy accurately to determine the pressure of fluidity of clay.

The curves (Fig. 1) brought out the phenomenon of the

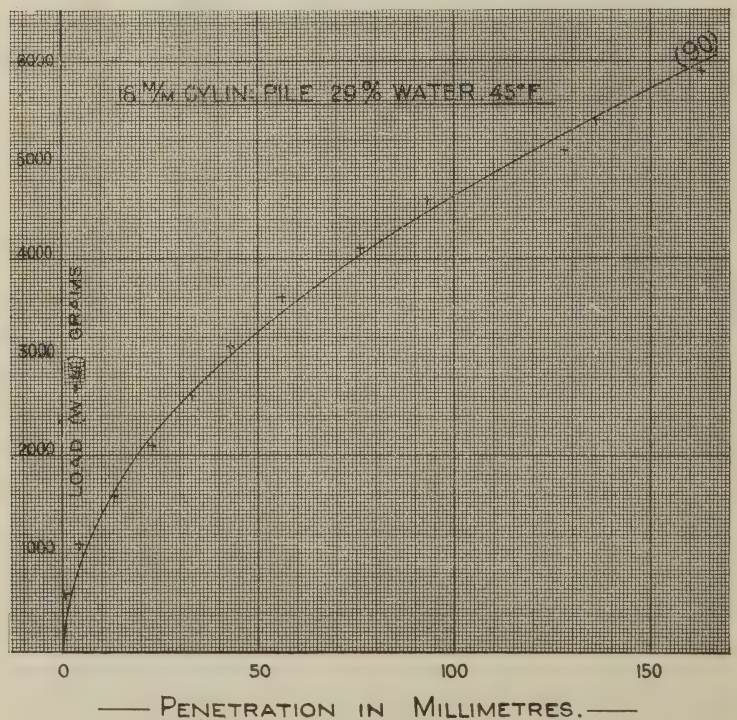


Fig. 2.

pressure of fluidity quite clearly. The curve (Fig. 2) was a typical one for a cylindrical pile, and the curve forming Set XX. (Fig. 3) showed the enormous effect on the pressure of fluidity of a small change in the percentage of water contained in the clay. It would be seen that, for a certain portion of the curve, the abstraction of 3 per cent. of water increased the pressure of fluidity three-fold.

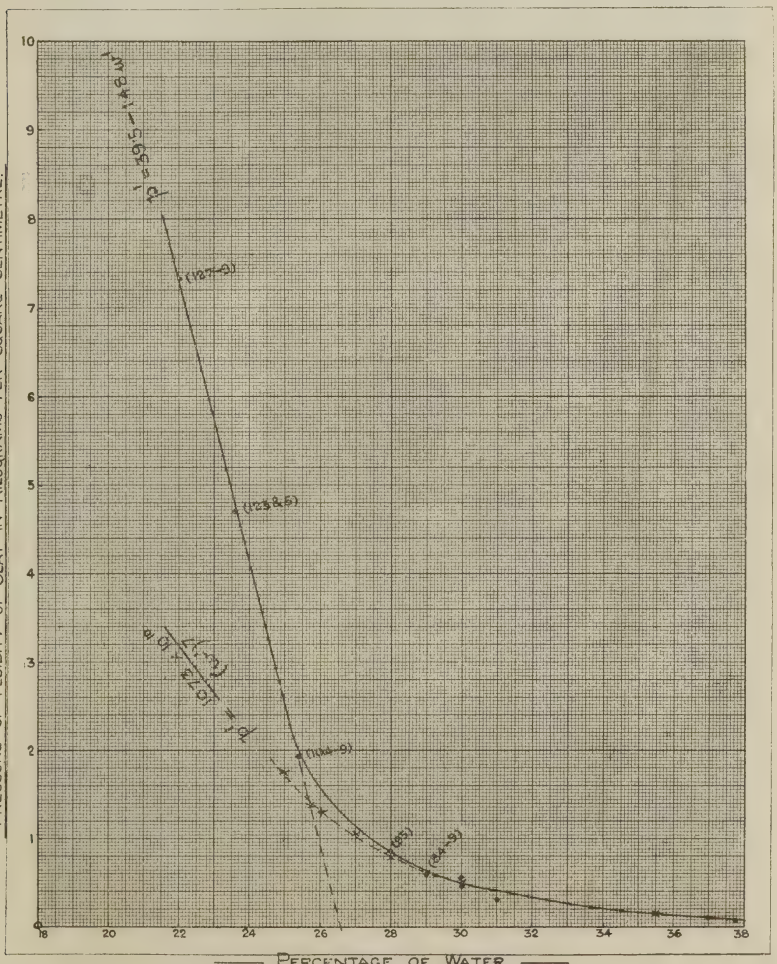


Fig. 3.

A series of experiments, which would probably interest some of the members of the Ceramic Society, was that made on the

extrusion of London clay, containing 29 percentage of water, through circular sharp-edged orifices of different diameters. The

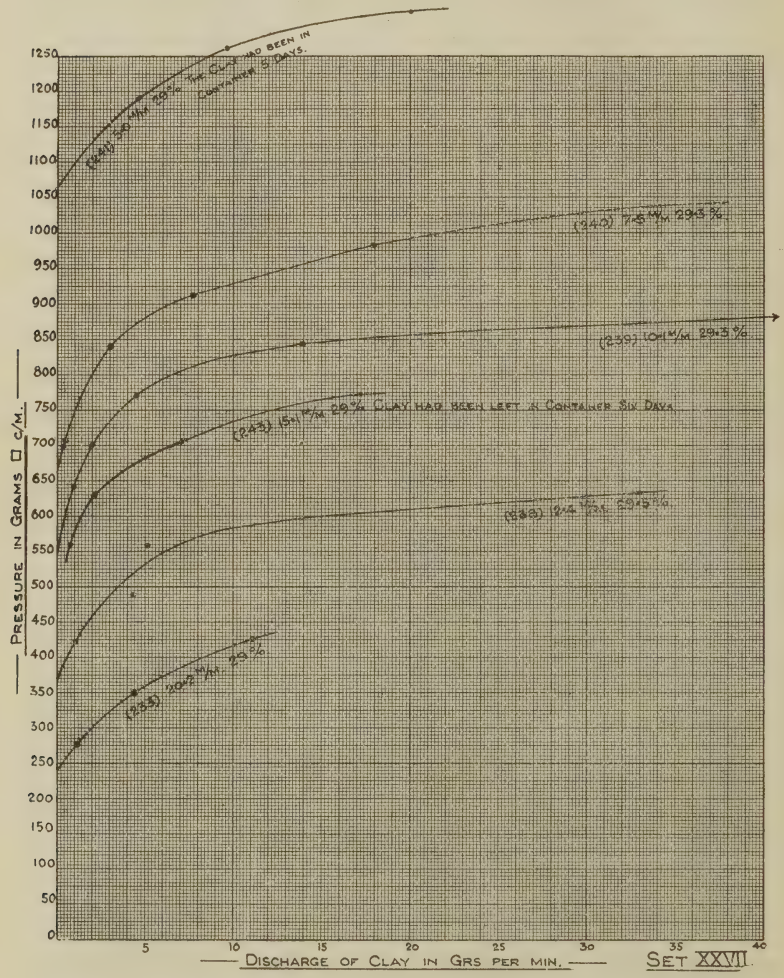

PRESSURE IN GRAMS □ C/M.
DISCHARGE OF CLAY IN GRS PER MIN.
SET XXVII.
(238) 5·0 M/M 29·5% THE CLAY HAD BEEN IN CONTAINER 5 DAYS.
(240) 7·5 M/M 29·3%
(239) 10 M/M 29·3%
(243) 15 M/M 29% CLAY HAD BEEN LEFT IN CONTAINER SIX DAYS.
(242) 20 M/M 29·5%
(235) 20 M/M 29·2%

Fig. 4.

results of these experiments were shown by the curves forming Sets XXVII., XXVIII., and XXIX. (Fig. 4–6).

The first of these showed a phenomenon similar to that of the pressure of fluidity, namely, that the curves tended to become horizontal as the pressure per sq. in. causing the extrusion reached a certain critical value. There was this difference, however, in

these curves, in that they did not pass through the origin; the clay needed a certain minimum pressure before any extrusion took place. Plotting these initial pressures, and the critical pressures, as ordinates and the diameters of the orifices as abscissae, curves forming Set XXVIII (Fig. 5) were obtained, but probably the most interesting

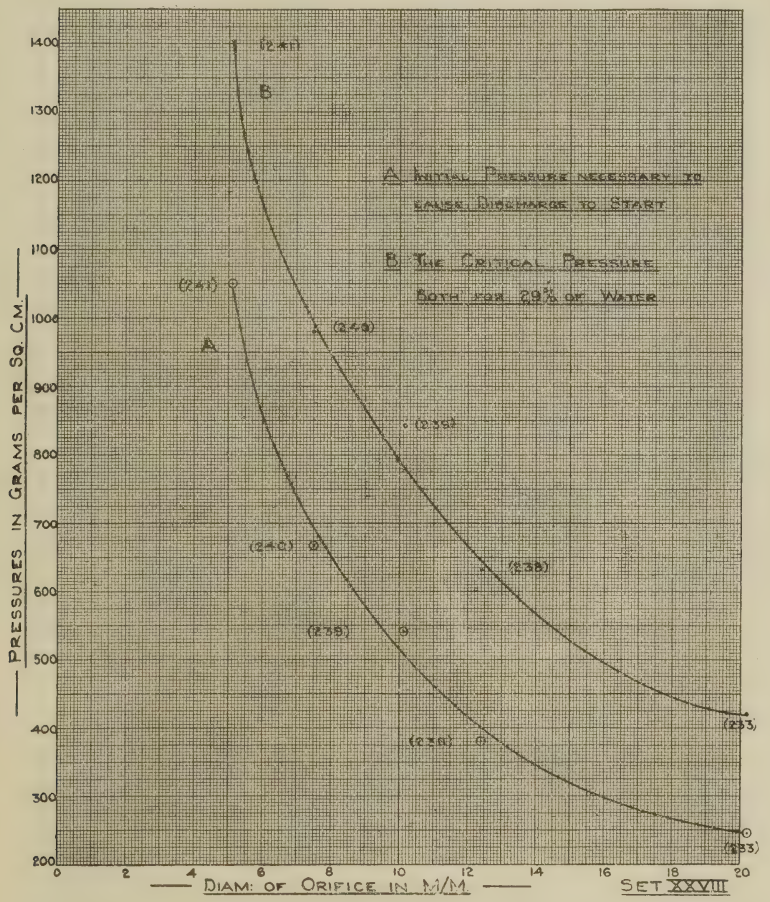


Fig. 5.

results obtained from these extrusion experiments were those which were illustrated by the curves forming Set XXIX. (Fig. 6). These showed that not only, as would be expected, was the discharge from a larger orifice larger by reason of it being a larger orifice, but it was also larger because each sq. mm. of its area discharged a greater quantity than a sq. mm. of a smaller orifice when the pressures were the same. For instance, when the pressure causing the

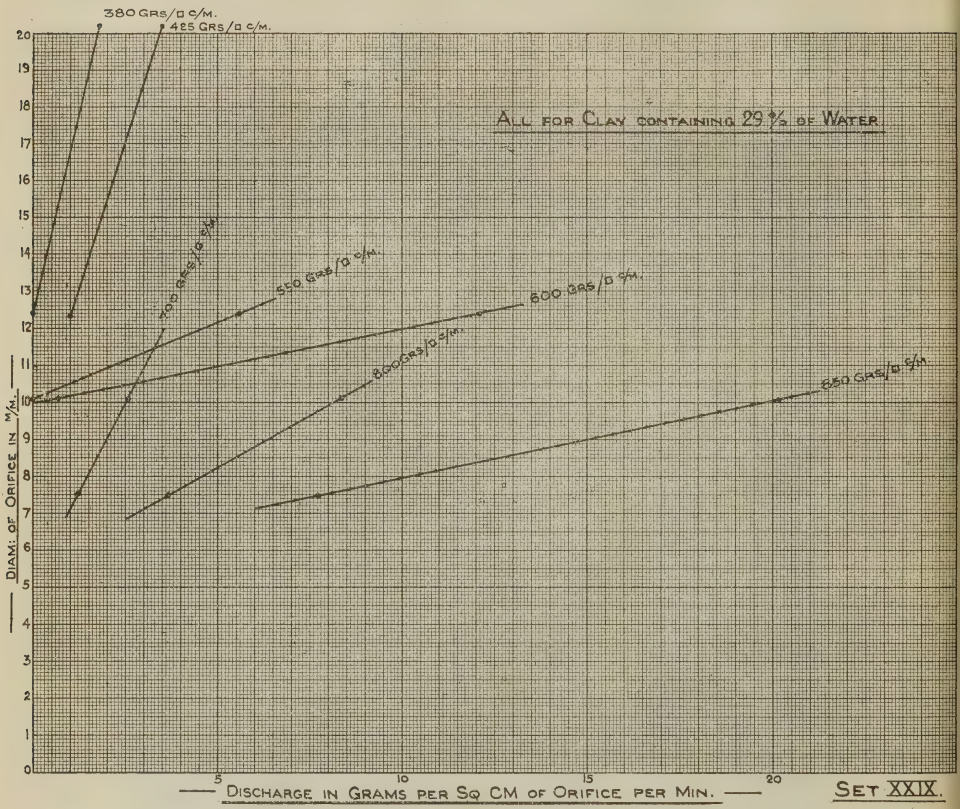

380 GRS/□ C/M.
425 GRS/□ C/M.
ALL FOR CLAY CONTAINING 29 % OF WATER
500 GRS/□ C/M.
550 GRS/□ C/M.
600 GRS/□ C/M.
650 GRS/□ C/M.
DIAM: OF ORIFICE IN M/M.
DISCHARGE IN GRAMS PER SQ CM OF ORIFICE PER MIN.
SET XXIX.

Fig. 6.

extrusion was 800 grms. per sq. cm., the 7·5 mm. diam. orifices discharged at the rate of 3·7 grams. of clay per sq. cm. of orifice per minute, but when the 10·2 mm. diam. orifice was used with the same pressure of extrusion, then each sq. cm. of this orifice discharged 8·4 grams. per sq. cm. of orifice per minute.

The effect of different pressures with the same pair of orifices was clearly brought out by the same set of curves, XXIX. (Fig. 6). When water was discharged through sharp-edged circular orifices, the discharge for a given head was directly proportional to the area of the orifice, and nothing else; but in the case of clay it was seen that, with the conditions under which the experiments were made, on doubling the area of the orifice the discharge was about quadrupled! Put another way, in order to get double the quantity of water out of a given orifice the head of water had to be quadrupled, but, in the case of clay under the conditions of the experiments,

this was not so. This was an unexpected and remarkable result of considerable practical importance.

DISCUSSION.

Mr. W. LINDLEY:—Mr. Ackermann's paper has taken my mind back this morning to an experience that I had, years back, in a somewhat remote part of Southern Europe, where I was actively interested in some rather extensive additions to an existing pottery. We had a lot of poor marl at our disposal and it occurred to me that we might be able to make some of our bricks for the foundations of the new buildings and so reduce the cost. We found, unfortunately, that when bricks were made of this poor marl, and hardened in the sun, they broke asunder; but by mixing this very poor marl with mud from the river we got very satisfactory results. However, we found ourselves up against the Government, who could not grant permission for the extraction of this mud without passing a special Act of Parliament. I was faced, therefore, with having all the machinery with which to make bricks but no satisfactory material with which to make them. I had been reading about the old Egyptians making bricks without straw, and I conceived the rather desperate idea of mixing straw with the marl in the grinding mill. I put the idea to the test and afterwards got no more trouble. This arrangement enabled us to push on with the whole of our extensions, comprising in all about twelve ovens, together with the surrounding buildings, and they are in existence to this day. The effect of the straw was to hold the bricks together until the sun had completed its drying.

MR. C. A. KING.—(Contributed):—While in general agreement that scientific work carried out on a small scale may be transferred direct to a more extended working scale, if any reservation should be made, it would be in the case of clay. It is well known that clays, even in close proximity to one another, exhibit marked differences in physical character, and it is not easy to see how experiments carried out on a small scale with artificially packed clay can be translated, for example, on to areas of naturally bedded clay even if the latter could be assumed to be homogeneous. It would be interesting to know whether, in the extrusion experiments, the pressure was observed at the surface of the clay or just before entering the dye.

The writer takes this opportunity of withdrawing his expression of doubt, as to the validity in extending the penetration results to steel, (Soc. Engineers 1922) and agrees with the author that the same law should hold for all homogeneous materials.

XXVII.—The Behaviour of Clays, Bauxites, Etc. on Heating. II.

By

H. S. Houldsworth, M.Sc. and John W. Cobb., C.B.E., B.Sc., F.I.C.,
(*Fuel Department, The University, Leeds.*)

Changes in Porosity, Density, and Refractive Index.

THE earlier work carried out by us on this subject (p. 111) had shown that the permanent shrinkage of Clays on heating was not continuous, but occurred in well defined stages; the principal shrinkages with kaolin being noted at 530°, 880°, 950°, and about 1,050°C. It was shown that these sharply defined shrinkages at definite temperatures were not due to corresponding stages in dehydration (which was nearly completed at 450°C.), and also that thermal changes in the kaolin on heating were confined to a heat absorption at 500°C., and an evolution at 950°C. We had found previously (Trans., **21**, 237, 1922), that when Meanwood ganister was heated to 1,000°C. a considerable increase in porosity without any appreciable alteration in the crystalline character and specific gravity of the quartz, was responsible for a permanent expansion, and it was considered necessary, therefore, to determine how far, if at all, the permanent shrinkages shown by clays on heating were due merely to decreases in porosity as distinct from volume changes in the clay material itself. Cubes were moulded from kaolin, dried, and heated for 24 hours in an electrically heated muffle at 100°C., and at every succeeding 50°C. up to 1,000°C., two cubes being burned at each of the temperatures selected. Preliminary experiments showed that no change which would influence appreciably the results here recorded took place on firing for a further 24 hours at any one temperature. In order to trace changes in structure as indicated by an altered behaviour towards light, kaolinite crystals (obtained from Mr. F. H. Butler) were also heated in the same way for 14 hours, and, after cooling, their refractive indices were determined in sodium light by the Becke method, the index of refraction of the oils used being found with an Abbé refractometer. The results of observations on the cubes and crystals are collected in Table I. and are shown graphically in Fig. I.

Part IV. Change in Porosity.

The porosities of the test-pieces were determined by immersing a dried specimen of known weight in paraffin under reduced pressure in a vacuum desiccator for 120 hours, then finding its weight

TABLE I.—CHANGES ON HEATING KAOLIN.

	True Density of Material.	Bulk density.	Porosity %	Refractive Index.
110°C	2·642	1·403	46·9	1·564
400	2·642	1·403	46·9	1·564
450	2·521	1·298	48·5	1·543
500	2·510	1·270	49·4	1·518
550	2·511	1·258	49·9	1·516
600	2·514	1·257	50·0	1·522
650	2·529	1·252	50·5	1·518
700	2·542	1·253	50·7	1·522
750	2·553	1·256	50·8	
800	2·565	1·259	50·9	1·527
850	2·568	1·258	51·0	1·532
900	2·608	1·267	51·4	1·541
950	2·684	1·299	51·6	1·542
1000	2·688	1·309	51·3	1·549

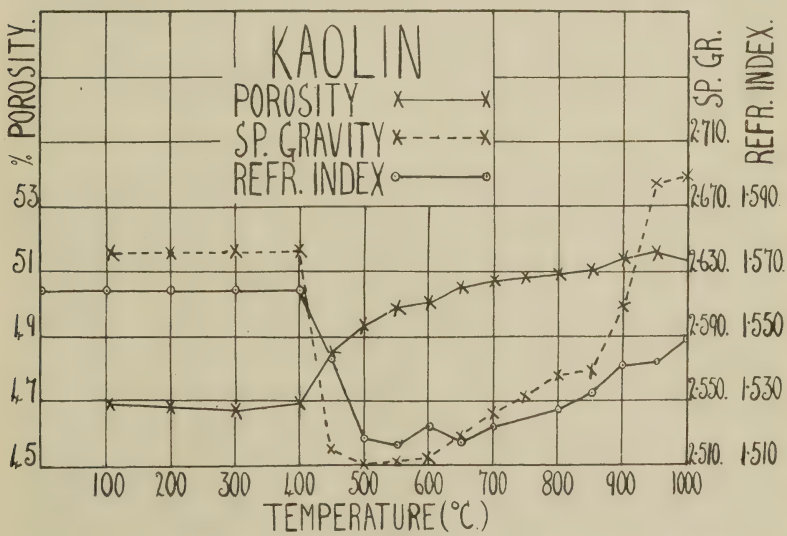


Fig. 1.

suspended in the paraffin, and subsequently weighing the saturated test-piece. The porosity equals: The weight of paraffin absorbed/Loss in weight of saturated test-piece on weighing in parafin. It is, therefore, the percentage of the total volume of the test piece occupied by open pores to which paraffin could penetrate.

The porosity did not change between 100° and 400°C. but increased by 1·6 p.ct. on heating for 24 hours at 450°C., the temperature at which rapid dehydration of the clay took place (see

Part II., p. 117). The porosity increased another 1·5 p.ct. on firing to 550°C. It should be remembered that the process of dehydrating kaolin at 450°C. is continued, although very slowly, after a 24 hour period, so that the further increases in porosity determined between 450° and 550°C. were probably due to the further slight dehydration of the clay as well as to any further chemical decomposition of the clay molecule or crystal unit which might have occurred. The porosity slowly increased on heating to higher temperatures, being 1·4 p.ct. greater at 1,000°C. than at 550°C. It was seen, therefore, that the shrinkages of the kaolin test pieces could not be attributed to decreases in their porosities..

We had hoped to apply the method of gas absorption described by Washburn (*J. Amer. Cer. Soc.*, **5**, 48, 1922) to the determination of the porosities so that the change in porosity of the same test piece could be determined after firing to different temperatures. The porosities determined in this way were on the average 8 p.ct. higher than those obtained by saturating the test pieces with paraffin. The specific gravities as determined from the paraffin experiments and by the bottle method agreed to ·005 and it was concluded, therefore, that there were no closed pores in the specimens, and that the high values for the porosities determined by the method of gas expansion were probably due to adsorption of air by the test-pieces.

Part V. Change in Specific Gravity.

The changes in the specific gravity of kaolin after heating at different temperatures were determined both by the bottle method and from the data obtained from the porosity determinations when paraffin was used for saturating the test-pieces. The true specific gravity of the clay remained unaltered up to 400°C., but decreased considerably (from 2·642 to 2·521) on firing at 450°C., a further. slight decrease (from 2·521 to 2·510) taking place at 500°C. It was seen, therefore, that the dehydration of the clay at 450°C. was accompanied by a pronounced decrease in its density, the further smaller decrease at 500°C. being due presumably to the completion of the dehydration and of any other molecular decomposition occurring at 450°C. It will be seen from Table I. that the true density of the kaolin had reached a minimum value when dehydration was complete. Little further change in specific gravity took place up to 600°C., but at 650°, 700°, 750° and 800°C., small increases in density occurred. These changes are in agreement with the slight shrinkages described at 625°, 680°, and 760°C. in Part I. There was only a small further change at 850°C., but on heating to 900°C., the specific gravity increased from 2·568 to 2·608. This change corresponded with the large shrinkage which took place at 880°C. A larger increase in specific gravity (from 2·608 to 2·688) was observed on heating for 24 hours at 950°C., this further change in all probability being associated with the large shrinkage occurring at 950°C. Little further change in density was detected at 1,000°C.,

the small increase noted being due probably to the completion of the change occurring at 950°C.

It was seen, therefore, that pronounced changes in the clay molecule, as indicated by alterations in the specific gravity, occurred at 400–450°C., 850–900°C., and 900–950°C. corresponding with the dehydration of the clay at 450°C., and the shrinkages at 880° and 950°C. respectively, while smaller changes took place at 600–650°C., 650-700°C., 700–750°C., 750–800°C., and were probably associated with the small shrinkages observed at 625°, 680°, and 760°C. respectively. These latter changes may possibly be due to changes in the small quantities of impurities present in the clay, rather than to the kaolinite itself. It will be seen from Table I. that dehydration was accompanied by a decrease in the bulk density (*i.e.*, the weight of 1 c.c. of the test-piece), although no expansion accompanied dehydration. It should be noted, however, that if a body suffers a loss in weight of 12·8 per cent. without any change in volume taking place, its bulk density would be decreased by 12·8 per cent. The results indicated that, if no change in volume had occurred, the clay had lost 10 to 11 per cent. by weight. It must be remembered, however, that the figures given for the bulk density are not so accurate as those for the true density of the material, as errors of 0·2 are possible in the values obtained for the porosities, while the possibility of slight variations in the porosities of different unfired test-pieces must not be neglected.

It will be seen from Table I. and Fig. 1. that the refractive index of the kaolinite crystals was not altered by firing at 400°C., but that it decreased from 1·564 to 1·543 on heating at 450°C. due, no doubt, to the dehydration of the crystals. The refractive index decreased from 1·543 to 1·518 after heating to 500°C. and this further decrease was probably due to the completion of the change taking place at 450°C. It will be seen from the Table that the refractive index, as well as the specific gravity, attained a minimum value when dehydration was complete. After this stage the crystals were not so transparent as before dehydration, and the refractive indices were more difficult to determine. The possible errors of experiment were then of the order $\pm$·003, whereas the refractive index of the original crystals was correct to ·001. It was seen that little change in refractive index took place from 500° to 700°C., but that at 800°C. the index of refraction increased slightly, the increase being more pronounced at 850° and 900°C., a result caused probably by the same change as that producing the shrinkage about 880°C. Practically no further change occurred at 950°C., but a further increase in the refractive index was detected at 1,000°C. This was probably due to the change producing the shrinkage at 950°C., which might have occurred at a slightly higher temperature with the pure kaolinite crystals than with the less pure kaolin.

Summarising this part of the work, it would seem that definite changes in the kaolinite molecule, or crystal unit, as shown by

changes in the specific gravity and refractive index, occurred about 450°, the temperature at which rapid dehydration began, and at 880°, and 950°C., where large shrinkages were observed together with a rapid evolution of heat at the latter temperature. The results indicated the possibility of minor changes at 625°, 680°, and 760°C., at which temperatures kaolin exhibited very slight shrinkages. The porosities of the test-pieces increased gradually as the firing temperature of the kaolin was raised up to 1,000°C. The true density of the kaolin, and presumably the bulk density and the refractive index of the kaolin crystals, had reached their minimum value when dehydration was complete.

XXVIII.—Question Box.

1—*Question*—Are silica bricks suitable for pottery ovens and kilns in positions such as immediately above bags, midfeather, etc.?

Mr. S. S. Riley:—No. It has been my experience to give silica bricks a good test in most parts of earthenware ovens (glost and biscuit) and kilns, and I find that as regards temperature (earthenware), they are quite unaffected when used in bulk in the hottest parts. If used in exposed positions such as bottoms and tops of bags, midfeather, etc., they will not stand the cooling down after firing; they simply "crumble," and fire mouths opposite doors will always be found to suffer the most from this defect. They last longer in biscuit ovens than glost—I think on account of the longer time taken in the cooling.

2—*Question*—What is the cause of the frizzling in the enamel red on the sample plate submitted?

Mr. H. E. Wood:—In the absence of any knowledge as to the particular colour used, I should think the fault was due to the colour, because, as you will see, it occurs wherever the colour is thick. If I had to deal with this fault, I should look principally to the printing to see that, in mixing the colour, not too much oil was used. I should then watch the treatment of it in the kiln. In the first place, I should take care that it was not rushed into the kiln; and secondly, I should see that the kiln was fired regularly, so that the colour might be given every chance during the early stages of firing. If these precautions failed, I should feel disposed to abandon the colour and substitute another.

Mr. J. Miles:—I would like to add to Mr. Wood's suggestions: Keep away from the side of the kiln. This particular colour, so far as my experience goes, requires to be well sheltered.

3—*Question*—What is the best method of removing brown discolorations, known as "breezed," from large pieces of biscuit ware?

Mr. W. Lindley:—What we do is to rub the piece down well. Of course, if it is very hard fired, then the rubbing-down takes a rather long time. We do the rubbing by means of a carborundum stone, or at least a stone made specially for the job. I do not know of any way of curing this fault other than by the application of rubbing.

Mr. H. E. Wood:—Like Mr. Lindley, we resort to rubbing to get over this difficulty. I believe that other methods have been tried, such as hydrochloric acid; in fact, we ourselves have tried a good many; but we have found that elbow grease, with the help of a carborundum stone, is the best and cheapest method in the long run.

Mr. Bernard Moore:—I believe by far the best method of removing this fault is the sand blast. To my knowledge it is used by many sanitary ware manufacturers, and it is quite possible to use it with good effect.

Mr. H. E. Wood:—We tried that too, but we found that rubbing was the better method. It may be that our sand blast was too elementary; but that was certainly the result.

Mr. Bernard Moore:—I have seen the sand blast method employed for pieces which could scarcely be dealt with by rubbing on account of their shape. I can only say that I have seen the sandblast method employed quite extensively; not merely for a single piece or a few pieces, but for ten, fifteen and twenty pieces at a time.

Mr. H. E. Wood:—We did some hundreds of pieces, and we eventually reverted to the rubbing.

4—*Question*—What is the best surface factor for (*a*) an earthenware body, (*b*) a china body, (*c*) a sanitary body, and (*d*) a tile body?

Mr. B. Moore:—Before attempting to give an answer to this question, I would like to be quite clear as to what is meant by "surface factor." For many years, attempts have been made to define the amount of grinding which a pottery material has received by endeavouring to calculate the sum of the surface areas of all the particles. In order to do this, it is necessary to calculate the mean diameter of the various fractions. Dr. Mellor has shown in a very ingenious way how this could be done, if an assumption were made as to the grading of the various fractions. As there are no reliable data of this grading, the assumption is made that the grading is all equal, and the figures which have been used of late years to calculate the surface factor of pottery materials have been based on this assumption. The materials are, however, never equally graded; there is an enormously larger proportion of the finer fractions as compared with the coarser. This vitiates the surface factor in use to a considerable extent, and although it may be used, with great advantage, as an indication in comparing one sample with another, the actual figure given is not accurate. I will say nothing about the variation produced by different specific gravities. I alluded to this in a short paper, which I read a few months ago on

allutriation (*cf.* TRANS. **20,** 112, 1921). There has been an increasing tendency to claim for material having a high surface factor properties which it does not possess. The majority of Potters who have considered the matter, seem to think that there is a law to the effect that the finer one grinds one's raw materials, the more active they become in the body. Now, although this may be true in the main, it is not a universal law, and if this is not recognised, certain problems continually arise which are difficult to understand.

There are other factors also to consider: *e.g.*, one might have two indentical bodies, which mature at different temperatures; one might also use two materials of the same chemical composition but with different surface factors, and the activity of the material having the lower surface factor might be greater than the one with the higher. As far as I know, this view has not been put forward before, but it is undoubtedly true, and we have numerous examples of it in the pottery industry.

I maintain that the surface factor *per se*, even if it is the correct one, is not necessarily, as is generally supposed, an indication of the activity, or otherwise, of the material in the body. It is true that the rate of reaction in finely-ground material is generally greater than in coarsely-ground material, principally, perhaps, because there are more points of contact. The packing together of the various particles, however, plays an important part; hence we find that a pressed piece matures more readily than a cast piece. We have all seen a pressed teapot with a cast spout, in which the latter has crazed; the rate of reaction has been greater in the pressed than in the cast piece, although the surface factor was the same for both parts. Similar differences are seen in tiles, where varying amounts of moisture are used in the dust. The surface factor alone does not tell us how the material will pack. Material with a very high surface factor may occuply more space than one with a lower. The whole subject is very interesting and fascinating. I have found it so important, that I am fitting up a small room to study the problem. I hope that in future, we shall arrive not only at a definite surface factor, but also at a definite grading.

Pressure plays an important rôle in pottery reactions. This was recognised instinctively by the old potters. Josiah Wedgwood's instructions as to the slapping of clay (*vide* p. 278), although the reason was not pointed out, are testimony to the fact that the same body may mature at different rates and produce wreaths.

A graded sample packs more closely than an ungraded one. The conditions which pressure brings about in a pressed piece, *i.e.*, closer contact of the particles, can be effected by mixed grading. Pottery bodies are composed of materials which vary in their degree of fineness and in specific gravity. The materials are also mixed in varying quantities. The fact that potters found it

advisable to have two different degrees of fineness for the same body, fired in the same oven and dipped in the same glaze, would be unintelligible to me, if what I have put before you were not true. In my paper on elutriation, I put forward a graph, which assumed that the grading of each fraction was similar to the grading of the whole, and also that flint, which had been well ground and well washed up, contained approximately 50 per cent. of 0·01 and 25 per cent. of 0·02. Since that time, I have examined a large number of samples, which I considered satisfactory, and I found that these samples agreed fairly closely with the above assumption. It will be seen from this graph that the more the material is ground, the higher the proportion of the finer fractions, and *vice versa*.

I am of opinion, therefore, that pan-ground material, which has been well washed up and does not contain more than about 25 per cent. of material larger than 0·02 mm, is satisfactory for general earthenware. Sanitary ware may leave up to 30 per cent. in the elutriator. For tiles it would probably be better if not more than 30 per cent. were left in the elutriator.

Mr. A. G. Richardson:—We all appreciate very much what Mr. Bernard Moore has brought forward, and we especially appreciate, I am sure, his wish to do his best to set up a standard. I am convinced that both millers and manufacturers would welcome the setting up of some definite standard of fineness for flints. I know that many manufacturers have suffered badly from having their flints ground too finely, and I know that at the present time the millers are being badly misled. I do not know where they have got their standards from, but they have certain standards which they have adopted, so far as I can understand, from something which has been said before the Ceramic Society suggesting that they should go to a certain degree of fineness for the really good grinding of flint. Some of the millers appear to have got the idea that they cannot grind too finely, and some of them are seriously acting upon this idea. Well, experiments have been made and papers given from time to time which have absolutely proved that excess of grinding as regards flints for Earthenware Bodies is exceedingly dangerous, from the potter's point of view. It leads to a fault that I have attempted to demonstrate in regard to the use of grey flints; it brings peeling and dunting. I cannot quite understand where the miller of to-day has got hold of the idea that to grind flint as fine as ever he possibly can is an advantage to the potter in the manufacture of earthenware. My practical experience goes to prove that it is a serious detriment, to the earthenware manufacturer at all events, whatever it may be to manufacturers of other kinds of pottery. If one wants to make a vitreous body, possibly there is some advantage in using extra finely-ground flint, but for an ordinary earthenware body one should avoid very finely ground flint as one would avoid poison, and the sooner the millers realise that over-fine grinding is dangerous, the better it will be for the

ordinary earthenware manufacturers at all events. I have heard of quite a number of millers who are very anxious to oblige the manufacturers by giving them the very finest flint obtainable. To my mind, such millers are simply laying themselves out, unwittingly, to give the manufacturer additional troubles. I am of the opinion that we should do well to give the millers to understand that such grinding is wrong. Unfortunately they do not see the results, and they do not appear to know what is happening. Quite a number of experiments have been made in the pottery classes from time to time, apart altogether from the practical work that has been done on our factories, which proves that grinding beyond a certain point is exceedingly dangerous. Therefore, I should specially welcome the establishment of some definite factor, as suggested in the question. I can quite see the difficulties which Mr. Bernard Moore has referred to, but the results with such classes of goods as dinner, toilet and teaware, which form the bulk of the productions of the Potteries, are more or less straightforward, and I am sure that a fairly safe standard could be found, and that this would be a very great help to all involved in the manufacture of the ordinary run of domestic earthenware.

MR. W. LINDLEY:—Might I ask whether Mr. Richardson would be quite so emphatic in advocating coarsely-ground stuff if he were making dinnerware?

MR. RICHARDSON:—I have never said that coarse grinding was good for anything. I said that excessively fine grinding was wrong. I also say that coarse grinding is equally wrong, because if you grind flint too coarsely you will have crazing, without any question. Which I thought was quite understood.

MR. BERNARD MOORE:—In actual practice I have found very little that is too finely ground, and if, as a result of this paper, the millers were to get the idea that they can supply flint more coarsely-ground than that which they already sell, I am afraid it would cause a good deal of trouble. It is extremely rare that you find in practice flint supplied for general earthenware that is too fine. On the other hand, there is nothing which has caused more loss in the Potteries than the employment of flint which is too coarsely-ground.

5—*Question*—What is the cause of the scum or deposit sometimes white and sometimes yellow in colour, which appears after biscuit firing on the edges of bowls and occasionally on the edges of plates?

6—*Question*—What is the cause of yellow edges on biscuit ware, the yellow extending about half an inch or more from the edge, the fault occurring on flat and slop bowls particularly?

Major B. J. MOORE:—I have been asked to reply to two questions this evening, both of which embody the same answer,

and I propose, therefore, to deal with the two questions in my answer, together with a short explanation of the faults and a few suggestions as to possible remedies.

This is due to soluble matter in the potters' slip. The principal and final drying of clay ware often occurs at the edges of pieces, hence the largest proportion of soluble salts are visible there.

Various anti-scums are on the market, the action of which is to render the soluble salts in the slip insoluble. Thus, if the soluble matter is calcium sulphate an addition of barium chloride in the proper proportion will form an insoluble barium sulphate and calcium chloride. This, however, does not always offer a very practical solution of the difficulty from a general earthenware point of view, because the amount of soluble sulphate in the clay slip will vary from time to time and it cannot be quickly estimated. If an excess of soluble anti-scum (say barium chloride) be added, it may in itself cause the scum and the cure may prove to be more troublesome than the disease.

It therefore seems to me more practical to consider briefly the principal sources of soluble matter in clay slip and try first to eliminate these or at least minimise them, and afterwards to deal mechanically with whatever scum is left.

Soluble salts may to some extent occur in ball clays. Therefore, weather your ball clays as much as possible by exposing them to the rain and frost and thereby remove the soluble matter. Mill materials may contain soluble salts, possibly added by the miller as "anti-set." Investigate and act accordingly.* The principal cause in my opinion is, however, the constant re-use of water from the filter presses. It seems to be common practice in the Potteries to have an ark under the filter presses to receive the water, and this is pumped into the blungers time and time again. It can easily be understood that in a very short time this water becomes more or less saturated with soluble matter and so your clay pieces become more or less scummy at the edges according to the amount of this water that is used. A practical solution of the difficulty is to use water from the filter presses for the scrap blunger only, and to use clean water for the ball clay and china clay blungers.

It is advisable from time to time—say once a month or once a fortnight if necessary—to use entirely clean water and to run off the water from the ark or receive under the filter presses; otherwise a more or less strong solution of soluble salts will be left, sooner or later, in the water contained in the potters' clay, according to the amount of dirty water that is used. Suppose, for example, that we start with perfectly clean water which can take up 1% of soluble matter into solution each time it is used. Assume

* Scraps from the potters' shops may be contaminated with small fragments from the moulds which are to some extent soluble in water.

further that 20% of the water used goes to the potter and is lost in evaporation and that 80% is re-used from the ark under the filter presses.

The first time of use 100% clean water takes up 1% soluble matter.

80%	contains	1%	,,	,,
100%	,,	1·8%	,,	,,
80%	,,	1·8%	,,	,,
100%	,,	2·8%	,,	,,
80%	,,	2·8%	,,	,,
100%	,,	3·8%	,,	,,
80%	,,	3·8%	,,	,,
100%	,,	4·8%	,,	,,

One often finds slipmakers using only dirty water from the filter presses on some days and perhaps all clean water on others. Since a proportion of about 20% of the total water used in slipmaking goes to the potter in the clay, and is lost in the drying processes, it should be simple to arrive at a standard as regards the amount of clean and dirty filter press water that shall be used each day, and further, as to how often completely new water shall be used.

It is important to make some definite rule and see that it is not broken without your knowledge. The mechanical removal of scum on the edges of articles can be practically carried out by "fettling" when they are quite dry. I am aware that this is difficult in the case of hollow-ware, since it creates a dust and it is necessary to work at a bench with a suitable exhaust. As regards flat, however, I have known the adoption of "towing," viz. the "fettling" and "sandpapering" of plates when quite dry before firing, to remove entirely the troublesome fault of "scumming" which often causes discoloured edges and chipping.

I do not propose to offer any definite comment on the discolouration; as I should first of all require to investigate the conditions under which it was produced. It is, however, possible that a slight flash during firing would cause the scum or flux to develop a yellow colour due to the presence of iron.

I hope my few observations may prove of some practical use to our friends who have submitted the two questions which I have endeavoured to answer.

7—*Question*—What is the cause of blistering in the samples of stone submitted, four being blistered, and four not?

(The samples sent in were as follows:—(1) *A* and *B*: A mixture of 5 hard purple, 2 mild, and 1 white. They were fired in two different ovens, cone 4 being bent in each case. (2) *C* and *D*: as above, except that in the case of *D*, cone 4 was well over, while for *C*, it was bent only. (3) *E* and *F*: The

same mixture as *A* and *B*, but a different hard purple stone was used. (4) *G* and *H*: Mild purple stone only, fired to cone 4. For *G* cone 4 was bent, but for *H* it was only just touched. Each pair of samples was cast in the same mould from the same jug-full of stone. All the samples were cylinder ground. There was no perceptible fault in the wares produced by these samples (*A* to *F*) and no great loss was experienced in any of the ovens in which these were fired. Many hundreds of other trials have been fired, and the blistering sometimes comes for many weeks together, and at other times disappears for long periods; sometimes it comes or goes in alternate ovens).

Mr. J. A. Callcott:—I should prefer to describe this fault as "bloating" rather than "blistering." If two samples were taken out of the same jug of stone and fired in different ovens, one coming out bloated and the other not, I should say that the fault was due to the firing and not to the material. What is there in the stone to cause bloating? On firing a piece of stone or felspar, certain changes take place. At 400° the water of formation begins to pass off, and should all have been driven off before 600° is reached. From 600 to 900° nothing perceptible takes place, but at 900° the fluxes in the stone begin to soften, and at 1,000° the alumina and silica are broken up. I think the fluxes begin to act on the free silica at about 1,000°, alkaline silicates being formed. The alumina, however, is not attacked until 1,080° is reached. I do not think the bloating is due, as is usually supposed, to carbon dioxide, but rather to the alumina, which, at the stage when bloating occurs, is diffused throughout the whole mass of stone in a free state. I think the bloating is due to the sudden heating, which causes the alumina to swell.

Blistering can be produced almost at will by using a mixture of 5 per cent. of buff stone and 95 per cent. of purple. Neither buff nor purple stone, if used alone, produce blistering. I do not think that pottery manufacturers or millers fully realise the important part which stone plays in a pottery body. I believe it is the most important material with which manufacturers have to deal. Buff stone contains about 5 per cent. of fluxes; hard purple stone about 9 per cent. There are some felspars which contain about 13 per cent. of fluxes. If a manufacturer is supplied with stone yielding about 7 per cent. of fluxes and obtains satisfactory results, he does not complain; but, if he were supplied with a stone which gave 10 per cent. of fluxes, he might as well add 40 or 50 per cent. extra stone to the body mixture; it would simply act in the same manner. The ware would come out over-fired, and the fireman would probably be blamed. The same remarks apply in the reverse direction to the use of buff stone. If one had 5 per cent of fluxes in a buff stone, the ware would be short-fired. I agree with Mr. Richardson that, if the millers would put their heads together

and really standardise the stone which they supply to the potting industry, so that it contained from 7 to 8 per cent. of fluxes every time, it would be a decided advantage, both to the manufacturers and the millers.

XXIX.—The Manufacture of Refractories in America.

By A. F. Greaves-Walker, Production Manager, American Refractories Co., Pittsburg, P.A.

Introduction.

Owing to the wide distribution of the refractories industry in the United States, the variations in the methods of manufacture due to local conditions and the different types of clay used in different parts of the country, it is obvious that this paper can only deal with typical plants and methods. There is a very considerable difference in the raw materials, plant layouts, products and fuels in New Jersey on the Atlantic Coast and three thousand five hundred miles away in California on the Pacific Coast. Wages, too, vary considerably in different parts of the country, and this has its effect on methods and equipment used, to some extent. Generally speaking, the refractories industry has been slower in adopting mechanical devices to replace hand labour than have other industries, but in this respect the advance has been generally much greater than in Europe.

The large centres of clay fire brick manufacture are located in Pennsylvania, Missouri, Kentucky, Ohio, Maryland and New Jersey, with smaller centres scattered throughout the country from coast to coast. The large centres of silica brick manufacture are located in Pennsylvania and Illinois with scattered plants in the Western States. The large magnesite and chrome plants are located on the Atlantic Coast, with a few smaller plants a short distance inland.

Fireclay Products. Practically all of the high heat duty fire brick are made of mixtures of flint fireclay and plastic bond clay, the flint clays having a fusion point of cone 32 to 36 and the plastic clays of cone 29 to 32. The percentage of the two clays used depends largely on the purpose for which the product is to be used and the method of manufacture. For medium and low heat duty fire brick plastic fire clays are used almost entirely.

Hand Made Process. A great majority of all shapes and many nine inch are made by this method. A typical flow sheet for a plant using this method would be as follows :—

Storage piles.	Conveyors or barrows to moulding tables.
Crusher.	Hot Floor and Tunnel dryer.
Elevator to bins.	Kilns.
Wet pans (solid bottom).	Stock Shed (burned brick).

Occasionally this is varied by taking the clay from crusher to dry pan and then tempering the ground mixture in a pug mill.

The crushing and tempering method requires little description. In the modern plants the clay is unloaded from cars or stored so that it either feeds by gravity or conveyor to the crusher which is attended by one man. The crushed clay is fed to the wet pans from bins which are arranged to deliver a measured charge. The pans are emptied either by a mechanical pan emptier or shoveled out by hand while in motion. The moulding tables may be either set flush with the floor or set up on legs according to the method of delivering the mud from the pans. Wooden gang moulds are used for nine inch and single or double wooden moulds for shapes. After the moulds are filled, "bumped" to fill the corners, the excess cut off with a wire bow and "slicked," they are carried to the hot floor and dumped by an "off-bearer." The off-bearer also washes and sands the moulds for the moulder. In the case of shapes the moulds are sometimes oiled instead of sanded. A moulding gang consisting of one moulder and two off-bearers will usually deliver 3,000 nine inch to the hot floor for a day's work or "task." When delivering to dryer cars set close to the moulding tables, one off-bearer is used producing the same amount of brick for a "day." On shapes, moulders often dump their own moulds either on the floor or on pallets which they place on the dryer cars. On large shapes two moulders may work together. A day's work or 'task" on shapes is determined entirely on the size and difficulty of moulding. Different standards obtain in different plants even on the same shape. Hand moulded nine inch are always repressed, usually in a hand repress. The repressing is done as soon as the bricks on the hot floor or cars become "leather hard" or fit for handling. Three men usually compose a pressing gang, a "pickup" who gathers the bricks on a barrow and delivers them to the presser, a presser and a "take-off" who takes the bricks from the press and either puts them on dryer cars for the final drying or on barrows from which they are "haked" up on the floor until ready to set. When running at full capacity, many plants work three shifts of moulders and repressers, the gangs relieving one another as soon as they finish their "day," which usually takes about 6 or 7 hours. The floors are kept at such a temperature that the nine inch brick are ready for repressing about 6 hours after being moulded. Shapes are dried more slowly according to their size.

Stiff Mud or Steam Press Process. A great many nine inch and shapes are now being made by this process. For many years bricks made in this manner were in bad repute due to lamination. This has been overcome to a very large extent, however, and bricks are now made which, for certain purposes, are superior to those made by any other process. They are particularly suitable for service where severe abrasion is encountered as in certain parts of blast furnace linings. A typical flow sheet of a stiff mud plant is

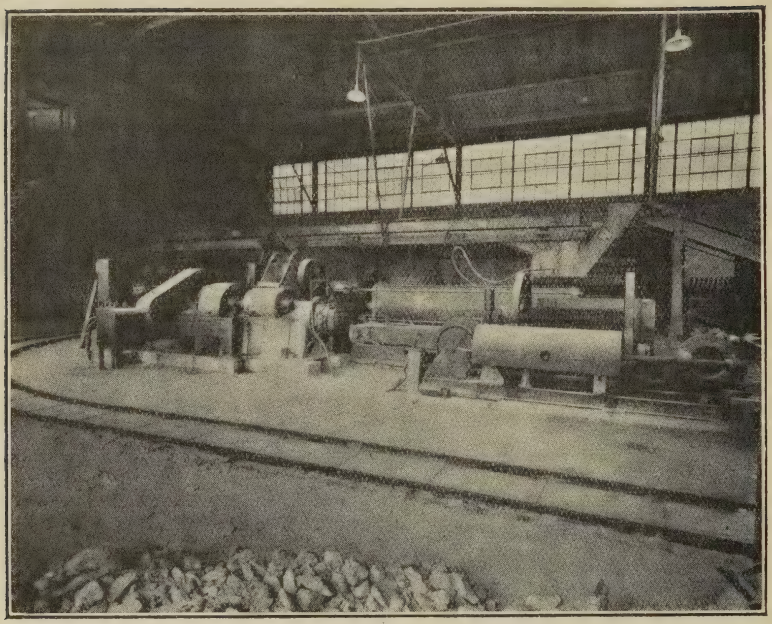


Fig. 1.
Stiff mud unit, showing pug-mill feed to brick machines.

as follows:—

Storage piles.	Brick Machine (Fig. 1).
Crusher.	Represses.
Elevator to Bins or Storage Piles.	Dryer Cars.
Dry Pans.	Dryer.
Elevator to Bins.	Kilns.
Wet Pans or Pug Mill	Stock Shed.

After preliminary crushing the different clays are either run into separate bins or storage piles, from whence they are delivered to the dry pans in the correct proportions either by gravity or by barrow. In some plants the different clays entering into the mix are ground in separate pans and delivered to separate bins. The proper mixture is then measured at the bin chutes by a Poidometer or measuring device, which also adds the correct amount of water, and this mixture is delivered to the wet pans or pug mill. In other plants the mixture is made at the dry pan, the pan tender shovelling in the proper proportions from piles delivered in front of the pan by barrows. In this case the bin delivers direct to wet pans or pug mills without measuring. In either case each dry pan is operated by one pan tender. One man also looks after each wet pan or pug mill. The pan or mill delivers direct to the brick machine,

which is also looked after by a "machine man." This man also looks after the automatic cutter, restringing broken wires. After leaving the cutter the bricks are delivered to an off-bearing belt from which they are picked up by the "pressers," run through the represses and placed on dryer cars by the "hackers." The cars are then pushed into the tunnel dryer. This is one of the cheapest methods of making fire brick, as the operation is largely mechanical. Two men take care of the pug mill, brick machine and cutter, and three men are required to handle the pressing of each eighteen to twenty thousand nine inch produced. Fairly large shapes such as $13\frac{1}{2}$ and 15 inch are produced in the same manner.

Soft Mud Process. The development of the soft mud machine process has not been so rapid as might be expected in the refractories industry, especially in view of the increasing difficulty of keeping hand moulders on nine inch.

Soft mud bricks are usually made with a fairly high percentage of plastic or semi-plastic clay. The process is generally confined to a dry pan grinding, pugging in a pug mill, forming in the brick machine and drying without repressing. It is altogether a cheap process and the product can be of high quality if the operation is intelligently managed. The grinding in the dry pans is as usual, the various clays and calcine being ground in separate pans and stored in separate bins. The mixtures are made automatically in a poidometer as the ingredients are delivered to the pug mill, and the water content is also controlled in the same manner.

The new automatic brick machines (Fig. 2) require but a small number of attendants, six men being able to make and handle from

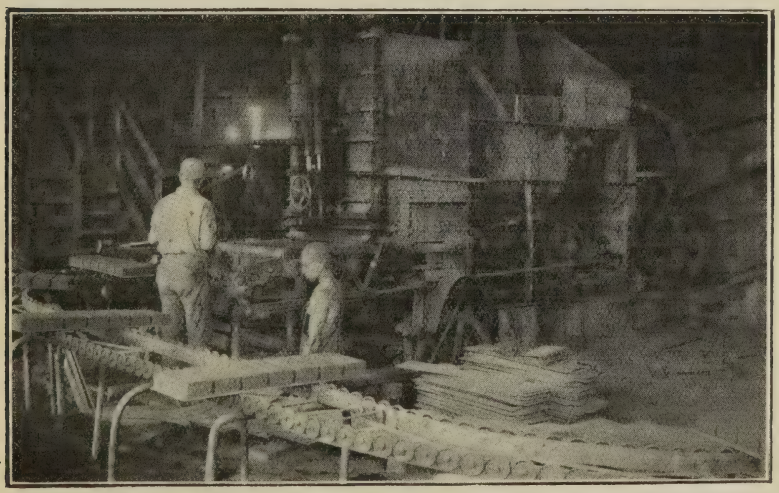


Fig. 2.
"Autobrick" machine producing 9-inch straights.

four to five thousand per hour. The machine sands the moulds, makes the bricks, dumps them and delivers them on pallets beside the dryer cars. The bricks are of good workmanship and it is not necessary to repress them, although this can be done if a smoother finish is desired. They are, however, dried to a leather stage if this is done. A typical flow sheet of a plant using this process is as follows :—

Storage piles.	Brick Machine.
Dry Pans.	Dryer Cars.
Elevators to bins.	Dryer.
Poidometer (Fig. 3).	Kilns.
Pug Mill.	Stock Shed.

Dry Press Process. This is a simple process and one much used in certain parts of the country where the clays are suitable. Formerly only soft clays were used in this process, but recently bricks made of one hundred per cent. flint clay have been extensively turned out. Four mould presses are used, which produce all nine inch and nine inch sizes and special rectangular shapes up to $24'' \times 12'' \times 3$. Recently, a larger press has been perfected, which will turn out special shapes up to four inches thick. The method of manufacture is by no means complicated, but some clays or mixtures of clays work very much more easily than others. As a rule the clays are stored in piles, which are soaked with water and allowed to stand for a certain number of days before using. They are taken from this storage and ground through a dry pan with the proper mixture of calcine. The mix is screened and run into bins above the presses. These bins are constantly stirred to keep the coarse particles from segregating.

From the presses the bricks are placed on dryer cars and these are run into a dryer and from dryer to kilns. The presses are usually operated at a speed which will produce from 1,800 to 2,000 nine inch bricks per hour. Two men are used to take the bricks from the press and place them on the cars. In the case of large shapes, they may be pushed from the press on to pallets. The pallets are then placed on rack cars, thus eliminating the necessity of handling the shapes until they are dry. Where especially dense bricks are required the mix is sometimes given a treatment in a wet pan or pug mill before feeding to the press. In this case the mix is usually allowed to dry out somewhat in piles after the pugging treatment in order to eliminate some of the water before pressing. A typical flow sheet for a dry press plant is as follows :—

Storage piles.	Dry Press.
Crusher.	Dryer Cars.
Storage.	Dryer.
Dry Pans.	Kilns.
Elevator to bins.	Stock Shed.
Mixer.	

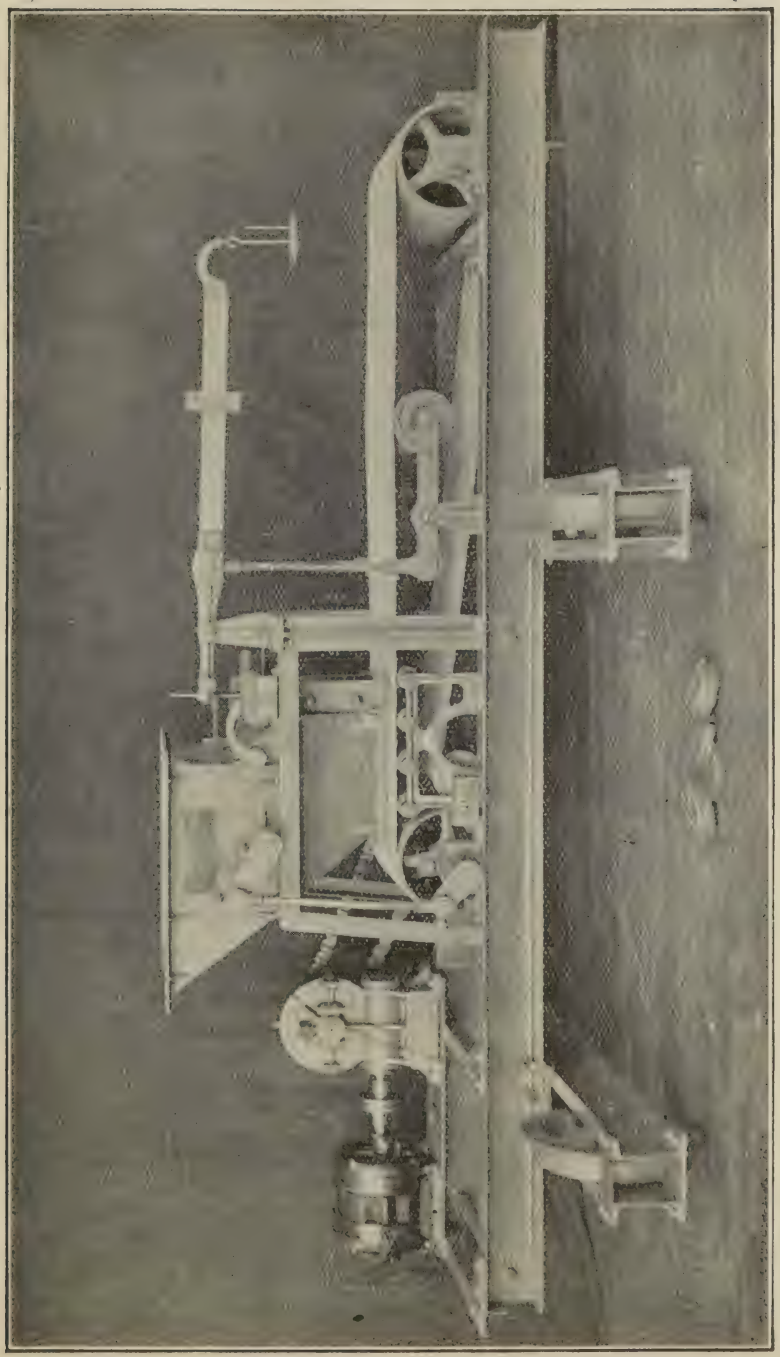


Fig. 3. Schaffer Poidometer for measuring mixes and water.

Drying Methods. The hot floor has been in the past the most popular means of drying refractories in America, but it is rapidly being replaced wherever possible by other types, principally the tunnel dryer heated by waste heat from cooling kilns. Hot floors are usually of concrete and are heated by steam pipes or flues buried just beneath the surface. Exhaust steam is used for heating while the engine is running and live steam direct from boilers when it is shut down. In some plants the roof of the tunnel dryer is used as a hot floor for drying special shapes, thus taking advantage of the radiated heat. The tunnel dryers are invariably heated with waste heat from cooling kilns.

In the past few years a number of plants have installed humidity dryers (Fig. 4). These dryers have reduced both the

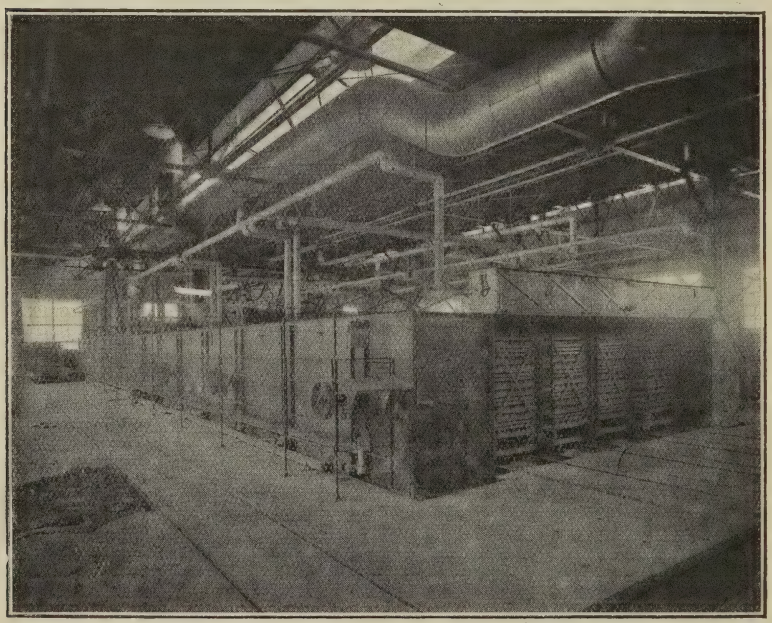


Fig. 4.
Humidity Dryer, Entrance End.

drying period and the breakage. The humidity dryer is divided into three chambers, each sealed off from the others by a steel drop curtain. All three chambers are carried at approximately the same temperature although the last or finishing chamber may be slightly higher than the others. In the first or entering chambers, which is tight, the ware is heated up to the drying temperature without losing any of its moisture; in the second chamber, a small percentage of moisture is withdrawn, and in the third the balance

of the moisture is carried off and the product discharged dry. The dryers are constructed to hold fifteen cars to the track, four being in the entering chambers, five in the middle chamber and six in the drying or discharge chamber. The dryer is heated with exhaust steam or hot air carried through large pipe hung on the side walls and the circulation is kept up by means of the series of high speed fans placed side by side the full length of the dryer on each side.

The temperature is automatically controlled and the handling of the rolling steel doors and the movement of the cars is done mechanically. The important point in the operation of this dryer is the maintaining of the proper amount of humidity in the first two chambers. When this is done the ware appears to dry evenly throughout its entire cross section.

Setting Methods. There is little or no variation from the standard methods of setting used in the refractories industry throughout the world. The number of courses in height is determined by the ability of the product to carry weight. As a rule, dry press brick are set only in the upper half or three quarters of the kiln to prevent excessive kiln marking, the lower courses being set with stiff mud or hand made brick.

Burning Methods. The round down draught kiln is still the favourite type in this industry. Usually, they are built thirty-two feet inside diameter, although in recent years some thirty-six and forty-foot kilns have been constructed. A thirty-two foot kiln, which would have a holding capacity of 100,000 if set up to the crown, is usually set to a capacity of from sixty to eighty thousand with fire bricks. In some sections of the country the down draught rectangular kiln is still considerably used, although few new kilns of this type have been built in late years. As the finishing temperatures vary so widely, it is impossible to strike an average on burning time and fuel consumption.

The continuous kiln is used on only one plant in the country. This kiln is of the chamber type and is producer-gas fired. This type of kiln will never be popular in the refractories industry.

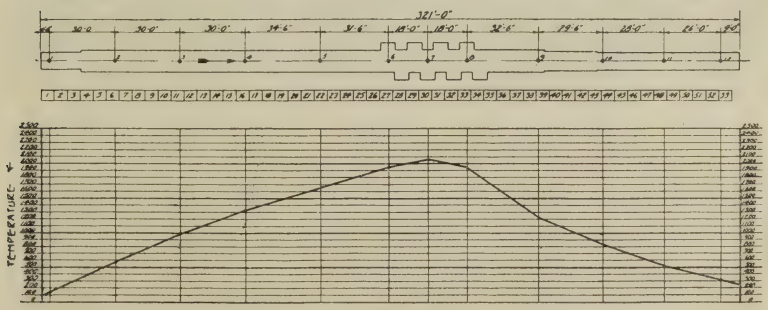


Fig. 5.
Temperature Record, Harrop Continuous Tunnel Kiln.

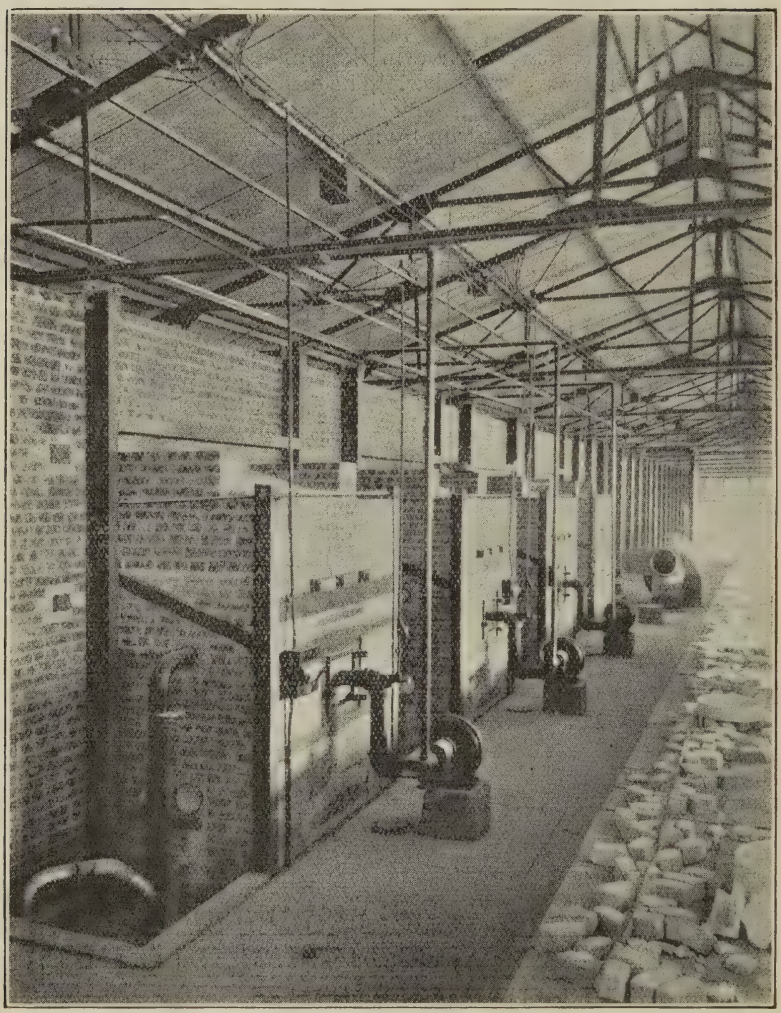


Fig. 6.
Harrop Continuous Tunnel Kiln. Furnace Section.

Several plants have installed railroad or car tunnel kilns (Fig. 5-7) and it is this type which will eventually be adopted by the industry to a very large extent. One of these kilns is a Dressler, and in it is being burned the most difficult glass house shapes with perfect success and practically no loss. This kiln is burning to cone 12. The other installations are of the open tunnel type. In the Mississippi Valley section the average burning temperatures in this

Fig. 7.
Fire clay shapes burned in Dressler Tunnel Kiln.

industry are below cone 10, generally about cone 7 or 8. In the Eastern section the finish is from cone 10 to 12. A few plants in the country burn to cones 14 or 15. The above refers to high-grade brick.

Silica Products. The old hand method of slop moulding is still used in making nine inch and nine inch sizes and in some cases in making 12 and 13½ inch rectangular shapes. Special shapes are made of slightly stiffer "mud", which is hammered into the moulds. The standard practice is to crush the quarried rock in jaw or gyratory crushers to sizes from 1½ to 2½ inches. This rock is elevated into bins above the wet pans and is delivered to them in measured charges, by a measuring hopper which fills and empties automatically. Milk of lime is discharged into the pans in measured quantities by gravity from lime tubs (hydrators) located in a room over the pans. Additional water is added according to the judgment of the pan tender. A pan will prepare from four to seven charges per hour, according to the hardness of the rock. The "mud" is delivered to the moulders by overhead trolly or elevated cars according to the design of the plant. Nine inch bricks are made in bottomless steel moulds, the moulds resting on a heavy steel plate while being filled. They are dumped on either galvanized or enamelled pallets which are placed on dryer cars and dried in

waste heat tunnel dryers. A moulder and helper produce three thousand bricks for a day's work. Special shapes are made in steel moulds equipped with loose liners, which are dumped with the shape. Deep moulds are partially filled and hammered with a wooden mallet, a large steel faced wooden "flatter" being used at the finish. As all American coke ovens are built of silica brick and shapes, the manufacturers are called upon to produce many exceedingly difficult shapes. Quite a large percentage of the capacity of the larger plants is taken up with coke oven and gas house shapes, which are also difficult. Nearly all difficult shapes are dried on hot floors, while the less difficult are placed on cars and put through tunnel driers.

Round down draught kilns of 32, 36 and 40 feet diameter are generally used and the product is burned from cone 18 to cone 20. The burning time varies from 6 to 12 days according to the characteristics of the rock used. Silica kilns are usually set to full capacity, *i.e.*, the setting is carried almost to the crown, only enough space being left under the crown to take care of the expansion of the brick. In a commercial burn, from 80 to 82 per cent. of the quartz is inverted. Before leaving the subject of silica brick, it will be of interest to note the development of a machine for making nine inch series and the more simple rectangular shapes. This machine has been in process of development for several years past and is rapidly nearing perfection. Several machines have been built and operated, and while these have had faults, they have demonstrated that the days of the hand moulder on all but difficult shapes are numbered. The machine similates the hand process in that sufficient mud to fill the moulds is dropped from a height that gives it the same force as would be used by a hand moulder in filling. The machine fills the moulds, strikes off the excess, "slicks" the bricks and dumps them in pallets. It also cleans and sands the moulds. Labour is used only to feed the pallets and take them away and place them on the dryer cars. A very small amount of power is required.

The cost of developing this machine has been borne by a number of silica brick manufacturers working under a co-operative agreement. The patents are owned by, and the use of the machine will be limited to, this group.

Magnesite and Chrome Products. Previous to the War, only one plant in America made machine-made magnesite and chrome bricks. Up to that time the process most used was to wet pan the magnesite grain or chrome ore and slop the mud into steel moulds, the bricks being later repressed and then slowly dried on a hot floor from 3 to 4 weeks or longer.

The method of making these products has probably been advanced more rapidly than in any other line of refractories. The present method is to grind the magnesite grain or chrome ore in mills of the same type as used in grinding cement clinker, to from 12 to 18 mesh. This product, after screening, is delivered to bins

above the wet or mixing pans. Measured charges are delivered to the pans by automatic weighing hoppers. The charge is simply moistened with sufficient water to make it bond in the hand when squeezed. This requires about four minutes. The charge is then delivered to bins above the dry presses and the process from then on is exactly the same as any dry press practice, except that the bricks being tender are delivered directly from the press to pallets, which are placed on drier cars. No bonding agent other than water is used. Special mechanical presses, however, which give nearly 10,000 pounds per square inch, have been developed which make four bricks at a stroke. Special nine inch sizes such as arches, keys and wedges, and special shapes up to twenty-four inches long by twelve inches wide by four inches thick are all made on the same machine. The product from the presses is run into a humidity dryer, which dries the nine inch in fifteen hours with little or no loss. Special shapes are given a longer drying according to their size.

Special shapes which cannot be made mechanically are made in steel moulds, the material being hammered into them with wooden mallets and the finish strokes with a steel faced wooden flatter. All moulds used in hand moulding have loose liners, which slip out with the brick when dumped. Round and rectangular down draught kilns are used to burn these products. In the round kilns the bricks are "boxed" to the entire height of the setting, *i.e.*, silica bricks are set so as to carry the weight of each magnesite or chrome brick. In this method, two silica bricks are set to one of the others. In the rectangular kilns, which are smaller and, therefore, burned off more quickly, the bottom courses are "boxed" and the upper courses are set without "boxing" in the regular manner. Burning takes from four to seven days according to the capacity of the kilns. Burning is done to cone 17 or 18.

Plant Equipment. Plant equipment in the refractories industry has been much improved during the past decade, with a resulting reduction in the labour required per thousand bricks produced as well as an improved product. In the case of storing raw materials, many plants have installed conveying equipment so that the clay or stone is dumped from the cars into crushers and the crushed product is delivered to storage piles or bins on a conveying system without further labour. In the case of silica plants this is carried further, as conveyors are provided which convey the material from storage to bins over the pans. The only labour required with these installations is men to dump the cars.

Portable, electrically driven car unloaders and conveyors have done much to eliminate labour in unloading raw materials and coal. These are self contained belt conveyors on wheels which can be used in series and their use is increasing rapidly. On most plants coal is distributed to the kilns with close coupled motor trucks with dumping bodies. Loading is done from bins or car unloaders which eliminate the slow shovel loadings.

The Schaffer Poidometer (Fig. 3), is now used to measure and weigh mixtures of clays and water automatically between bins and pug mill. This machine has eliminated the pug mill operator. Where wet pans are used, automatic weighing or measuring hoppers are installed in the discharge chute of the bin, which requires only the pulling of a lever in the hands of the pan operator to deliver a standard charge to the pan. The newest dry pans are ten feet in diameter with yoked individual mullers The additional screening surface contained in these pans adds greatly to their efficiency.

Stiff mud brick machines have been greatly improved in design, the newer types having enclosed gearing which permits the gears being run in oil. These machines, as well as most of the other equipment, are motor driven with chain instead of belt drive. The use of variable speed motors and chain drive has added tremendously to plant efficiency as well as conserving floor space.

Soft mud brick machines (Fig. 2) have also been greatly improved. The newest types sand the moulds, fill the moulds, strike off excess clay, bump the moulds, dump the bricks on pallets,

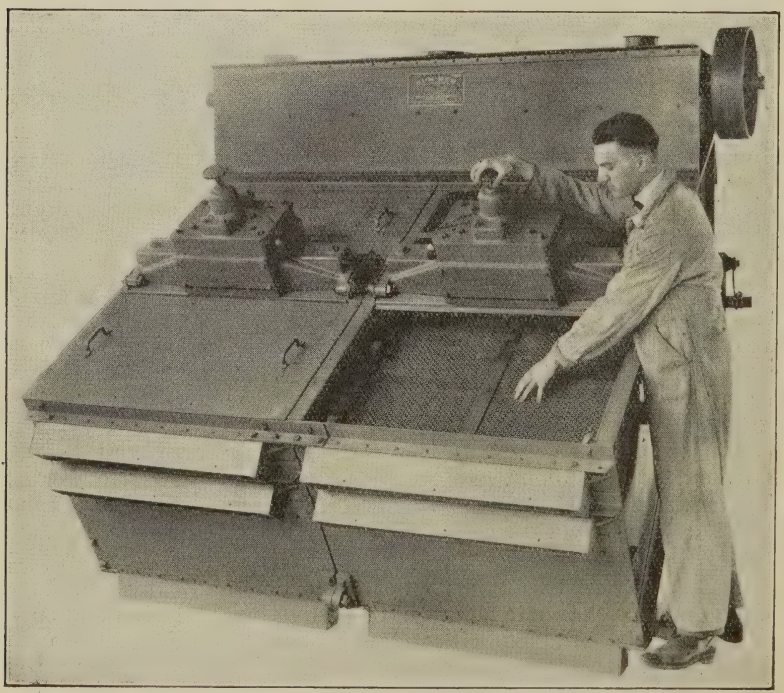


Fig. 8.
The "Hummer" electrically vibrated Screen.

put pallets on the conveyor and return empty moulds to the machine. Six men will produce from 4,000 to 5,000 nine inch brick per hour on these machines, handling pug mill, machine, pallets and drier cars.

Electrically vibrated screens (Fig. 8) have been another step forward. In these screens the wire cloth is kept constantly vibrating as the ground material passes over it, thus increasing capacities and giving a much sharper grading of the products.

Plant Organization. Practically the entire refractories industry is organised on a task basis. Whether it be mining or unloading cars of raw material, grinding, making, setting or wheeling, the men are given a certain tonnage or number of thousands to handle for a day's work and when the task is finished, they go home. On many plants operating only one shift scarcely a man can be found around the plant after 2-00 or 2-30 in the afternoon, except those employed around the kilns. Supervision is, therefore, principally confined to inspection in order to keep the product up to standard. In a plant producing from 50,000 to 100,000 bricks per day, the executive will usually consist of a plant manager or superintendent, a factory foreman who may have several assistants in a hand-made plant, a raw materials foreman, a setting foreman and a wheeling or shipping foreman. On some plants an assistant superintendent and a burning foreman are added to this list.

Wage scales in a large part of the industry are governed by the scale paid by the steel companies, an attempt being made to keep the common labour rate the same. The industry, as a whole, is fully alive to the necessity of cutting costs by eliminating labour and reducing coal consumption, and within the next few years, machines such as the automatic soft mud machine, and the silica brick machine, will cut further the use of hand labour, and the adoption of the railroad tunnel kiln will make a great saving in fuel consumption.

DISCUSSION.

Mr. J. Holland:—I would like to say that the diagrams intended for this paper only arrived in England a few days ago—too late to be included in the pre-print which is now before us. But they will be included later in the "Transactions." The paper has been a very valuable one. We had a similar paper last year from Mr. Rees, following upon his visit to America, when he was so splendidly received by the American manufacturers and afforded an opportunity of communicating to us anything that they are doing over there better than we are here. There is one thing that strikes me in connection with the present paper, and that is on the last page where Mr. Walker says: "On many plants operating only one shift scarcely a man can be found around the plant after 2 or 2-30 in the afternoon, except those employed around the kilns." I am beginning to wonder whether they have a football match in America every day, or whether the manufacturers are not out for making dividends. However,

I do not propose to take up your time. Doubtless there will be many of you who wish to discuss the matter, either now or by correspondence. But I would particularly like to ask Mr. Brooke whether he is yet able to beat the American manufacturers when they say that a silica pan will prepare from 4 to 7 charges an hour, according to the hardness of the rock. Could Mr. Brooke manage to get out as many as seven charges of Sheffield gannister per hour?

Mr. F. H. BROOKE:—The paper has certainly been a most interesting one, but I think that most of us in England did these things thirty years ago, or on very similar lines. What the Americans have done is to speed up the machinery. If you put rock through two crushers and break it down to half an inch or a quarter and you run revolving bottom pans at a speed of about 30 revolutions per minute you will get silica rock down—if it is not too hard—to about four charges an hour. But I have known some silica rocks that could be ground in considerably less time than that.

As regards kilns, there is no doubt that the Americans have gone one better than we have. They have gone in for larger kilns. Well, larger kilns have both advantages and disadvantages. At the same time, I do think that larger kilns are, in the long run, an improvement, and I believe that we in England will have to adopt larger kilns than we have done in the past. One has always to remember, however, that if silica brick is wanted out with a fairly quick delivery, a certain number of small kilns must necessarily be kept going.

There is one very good tool that they have in America, and that is, the discharging revolving bottom pan. The plant makers in England do not seem to have gone in for studying this aspect of the problem sufficiently. Undoubtedly it is a big advantage to be independent of discharging a pan over the pan side by hand shovels.

The humidity dryers are no doubt excellent for such productions as tankblocks and many of the shapes used by gas works, but as regards their advantages for 9-in. silica bricks I have yet to be convinced.

Mr. W. J. GARDNER:—I do not think I can add very much to what Mr. Brooke has said; but I notice that Mr. Walker calls attention to the fact that in gas works and coke oven shapes we have a very difficult problem in front of us. Mr. Brooke, yesterday threw out a hint to gas engineers and users of coke oven materials that they might do well to consider the utilisation of a standard shape which would minimise costs. Mr. Walker's paper suggests that the Americans are also feeling the pinch in this direction, and that should, I think, be conclusive evidence that something needs to be done in this matter.

I observe that Mr. Walker makes much of the point that in America they are now making by machinery silica bricks to imitate hand-made ones. I daresay that this machinery

is very valuable, but I really cannot understand why they still adhere to the practice of imitating the hand-made bricks. Perhaps some of my silica friends will disagree with me, but I am rapidly coming to the conclusion that the work that has been done by Dr. Mellor and his staff at Stoke, in regard to the question of a machine-made silica brick may, after all, if manufactured on certain lines, have a good deal in it. At the present time I am making experiments myself that are interesting and look favourable, and at a later meeting I may have something more to say on the subject. I am not at all sure that the Americans are acting wisely in adhering to this very fanciful machine.

So far as kilns are concerned, I find that the larger the kiln the more economically it will burn. A large kiln may have its disadvantages, as Mr. Brooke says, but there are distinct advantages in dealing with a large bulk at one time, providing the burning is carefully carried out. We, at Meltham, are saving something like 20 per cent. of our fuel consumption by the use of larger kilns.

The concluding point in Mr. Walker's paper is one that needs very careful consideration. I refer to the method of setting the men a specific task and allowing them to go home as soon as they have completed their work. My own experience is that this is rather a dangerous practice. It has a tendency to encourage bad work. If you are very keen, and you keep a big staff of overlookers, you may get over this difficulty somewhat, but the moment you set a workman on piece work—a British workman, at any rate—and give him to understand that as soon as he has completed his task of, say, one thousand or two thousand articles per day he can leave, he is disposed to rush and shuffle his work, in order that he may get away say at 3 instead of 5 o'clock. I do not recommend the practice at all, and I know many in the Industry who, I think, would confirm my opinion that it leads to a bad quality of work in the long run.

I endorse the remarks that have fallen from the other speakers that we are very much indebted to Mr. Walker for his paper.

Mr. R. J. Pickford:—I am afraid I cannot say very much about American practice because, unfortunately, I do not know much about it, and I have not had time to study Mr. Walker's paper. But there is one point that Mr. Brooke mentioned that I should like to emphasise, and that is with regard to the size of kilns. I think he is perfectly right in saying that there is an advantage in having large kilns, but I am afraid that, at any rate, under the present conditions of British trade, where we have so many different sizes and shapes to deal with, it is going to be difficult to increase materially the sizes of our kilns. This point is one that we ought to carry at the back of our minds all the time that we are thinking of larger kilns. We receive orders for so many small numbers of different shapes and sizes that if we are not very careful we are apt to get our large settings irregular, and a uniform result is problematic. At least, that is my experience

up to now, and we have not got kilns of anything like the same capacity as the Americans have. I do not think I am justified in trying to criticise any other part of the paper without further considering it. I should like to read the paper carefully and peruse the diagrams before I express any other opinions. I would, however, like to voice my appreciation of the paper.

Mr. H. J. C. Johnston:—With regard to the remarks in the paper that bear upon fireclay refractories, it would appear that the two outstanding points are the use of humidity dryers and of poidometers for weighing raw materials. It is a matter for considerable surprise that the English manufacturers have not yet adopted humidity dryers. The installation is not expensive and for blocks, retorts and heavy materials of that type it is undoubtedly an experiment that might well be worth trying. I do not know the poidometer which is referred to, but we shall be able to know more about it when we see the diagrams.

With regard to kilns, it seems a very remarkable statement which Mr. Walker makes that 20—40 per cent. of the space in these large kilns used for firebricks is wasted. A tremendous amount of heat must be consumed in heating up that waste space, and there must be some reason for it of which we are as yet ignorant. The only reason that I know of why kilns in this country are not set to the full capacity is the fear of the crushing of the material under the weight. But in up-to-date plants such as they have in America, one would have expected that this would have been provided for by the provision of kilns of suitable height.

On the question of plant organisation, it certainly seems a very remarkable statement, if Mr. Walker is speaking of plants where the output is produced by machinery, to suggest that it is economical for the plant to lie idle after 1-30 or 2-30 in the afternoon. I can well see the advisability of getting men to do their task in less time than the standard number of hours, but it would seem to be very much more economical to work a lesser plant or a smaller portion of the plant full time than to work the whole plant for a limited number of hours per day.

The only other thing I would like to mention is the last paragraph in Mr. Walker's paper having reference to the settlement of wages in the firebrick industry in America. I believe that very few of the firebrick works in America are associated with the manufacture of other kinds of fireclay products. The firebricks are not produced at the same works as enamelled bricks or terra cotta or drain pipes or anything of that kind. It would be extremely difficult—practically impossible—for us in this country to set up a standard rate for firebricks and silica bricks varying according to the wages paid in the steel industry, because there are so many brickwords which have no connection with the refractory industries, and these, of course, could not follow such an arrangement for general wages regulation.

Mr. C. R. Threlfall:—I would like to ask Mr. Greaves Walker whether he considers it possible to utilise a humidity dryer to accelerate the manufacture of the ordinary built-up gas-retort.

Mr. W. Hammond:—I would like to congratulate Mr. Walker upon his excellent paper. Good scope for discussion is always provided by a paper of this kind, and we can glean a great deal of knowledge from the discussion as well as from the paper.

With regard to the kilns, I think American kilns are very large indeed. It is certain that they are much larger than we use anywhere in this country, and I do not think that we could use such large kilns because of the point that has already been mentioned—the great amount of odd stuff that we have to deal with. Some of the shapes that our customers call for are extremely awkward to set in the kilns, and consequently, we could not manage with very high kilns. It is impossible to pile up to anything like a height such odd stuff as we have to deal with.

Mr. D. Thornton:—I cannot see that the adoption of these immense kilns, even though they were used for bricks only, would be of great advantage in this country. The risk is tremendous with a kiln of the size suggested. There is one advantage, as has already been mentioned in the discussion, and that is the securing of uniformity, and all brickmakers are at present troubled in this regard. The paper, being descriptive, has certainly been most interesting, and it should help to broaden our ideas when we read what manufacturers are doing in other countries.

Mr. J. Holland:—One point has just occurred to me in connection with these tremendous kilns. We must remember that America is a gigantic country, and we cannot attempt to compare the number of pieces used in our industries with the number of pieces that are used in the industries of the States. But whilst these gigantic kilns might be useful in America, inasmuch as they could possibly fill one per day, it would take us quite a long time to fill one. It might be well for us to try and think how difficult it would be for us to set up in this country a motor car factory on the lines of the Ford plant. The two cases are analogous, and this is one of the points that I think we must attempt to keep in mind.

Mr. C. A. King (Communicated):—As the paper is of a descriptive character, it does not lend itself to comment of a particular and detailed nature, and general comparisons only with English practice can be made. The practice of compounding a firebrick of materials of different qualities in definite measured proportions is preferable to the too general custom in this country of merely adding an indefinite quantity of grog, of uncertain character, to clay taken direct from the mine. It is doubtful whether American practice is far ahead, except in so far as the larger individual works have the opportunity for better mechanical handling operations. The use of tunnel dryers is mentioned

constantly, but it is interesting to note that most special shapes (silica) are dried on hot floors. The whole production of silica bricks, from the rate of grinding to the quantity made by hand, would appear to have been accelerated, and is beyond the normal output in England, where speed of making has had to be sacrificed to accuracy in size and shape. The descriptions of mechanical plant for making silica and magnesite products gives rise to the consideration of whether slop-making or dry-pressing gives a better brick, and in the writer's opinion, there is no doubt that the texture of a slop-made brick of this class is superior, probably owing to the "lubrication" of the particles, with consequent closer and better arrangement of packing, which no mechanical pressure can ever give.

XXX.—The Use of Refractory Materials in Gas Works.

By G. M. Gill.

AS is well known to those present in this room, the gas industry is a large user of refractory materials. To obtain gas from coal, it is necessary to heat the coal in a closed retort or oven, and the higher you heat the coal the more quickly and the more thoroughly you extract the gas from it. More than fifty years ago, it was customary to use cast iron retorts, in using which the temperature employed had to be very low compared with what are used to-day with fireclay and silica retorts. Coal gas is almost invariably made nowadays in either horizontal or vertical retorts. Inclined retorts, though still used to some extent, have gone out of fashion during the last 15 years, and a great many of such installations have been pulled out and replaced. Horizontal retort settings may vary in size from those with three single retorts of 10 feet in length to those having 10 or even 12 retorts of 23 feet in length, and these settings may be found in the greatest possible variety of design. While the design is a matter of great moment, the question of quality and suitability of refractory materials is probably of even greater importance.

Figures 1 to 4 show a design of retort setting brickwork, in which eight retorts, approximately 20-ft. long by 23-in. by 16-in., D-shaped, are set in one bed. Such retorts are heated by producer gas from a producer underneath. The producer gas meets with highly-heated air in the combustion chamber, the products of combustion passing round and heating the retorts, after which these products give up their heat to the incoming air in the regenerator.

A retort has not only to be heated sufficiently to carbonise the coal placed within it, but it has also to be maintained true to shape, level, and free from cracks and holes to enable it to be charged with coal and to be emptied of coke, and to give off all its gas without waste. Stoking machinery is somewhat rough with retorts, which need to be tough and durable to withstand their working, and also the contrast in temperature when the retort doors are opened for the hot coke to be pushed out and for a charge of cold coal to be put in ; and this takes place every 6 to 12 hours while the retort is at work. Periodically, varying at intervals of a few months to a few years, a retort setting will be let down from a working heat to atmospheric temperature and this process has always a severe effect on the retorts, which develop numerous cracks, all of which have to be stopped up before the retort can again be used. The normal expansion of the retort when heated and the

subsequent contraction when cooled account for the presence of these cracks in all retorts after they have once been cooled from a high to a low temperature. In fact, these cracks frequently appear before the retorts have been cooled down, and after the retorts have been "scaled" once or twice. This operation is rendered necessary by the fact that a layer of carbon, known as retort carbon or scurf, grows rapidly on retorts at work, increasing to a thickness of about one inch throughout the internal area of a retort in, say, two months' work, or sometimes considerably less, depending upon the way in which the retorts are worked. When "scaling" or "scurfing" retorts, it is usual to reduce their temperature somewhat, as this causes the carbon to contract and crack, when it is more easily removed with a long chisel bar. The cold air passing through the retort, the removal of the carbon, and the lower temperature of the retort combine to cause its contraction, and consequent cracking. It must also be remembered that the internal portion of the retort is called upon to withstand a great contrast in temperature, while the external portion is subjected to a steady and higher heat, and consequently, a variety of strains are set up in the walls of the retort.

It will, therefore, be realised that a heavy burden rests upon a horizontal retort, and it is not altogether surprising if it fails under the load. Experience teaches, however, that there are a large number of makers who can supply retorts which will withstand these conditions quite satisfactorily, though innumerable cracks will develop, for a life of well over 1,000 working days, provided that the temperature employed, as measured in the combustion chamber, is not allowed to exceed say, 1,280°C., which temperature was probably about the maximum employed, with few exceptions, until twenty years ago.

There is one factor, however, which greatly influences a retort's condition throughout its life, and also its length of life, and that is the nature of its support. Assuming that a retort is 20 feet in length, it will be supported upon walls of 4½ inch to 9 inch thickness, built with spaces of 8 to 12 inches between the walls. If these walls remain where built and do not expand or contract, the retort supported thereon has a much better chance of giving a good duty. A retort is naturally flexible to a very small extent only, and it is entirely dependent upon these walls to enable it to retain its shape, its level and true position. If, therefore, the walls are built of material which expands or contracts to any but a slight extent, the retort cannot possibly give satisfaction. Hence retorts are often blamed for what is the fault of the supporting walls.

Figure 5 shows a section through a setting of retorts and is taken from Meade's book on *Modern Gasworks Practice*. This view illustrates clearly the method of supporting retorts on crosswalls, which walls must remain where built, without expanding or con-

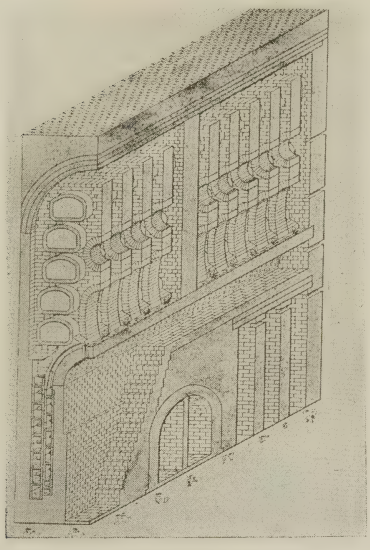


Fig. 5.

tracting, except to quite a slight extent, if the retorts are to be given a reasonable chance of fulfilling their onerous duties.

There is a large amount of retort and firebrick material available for purchasers, which will give satisfaction as long as the temperature mentioned above, viz., 1,280°C. is not exceeded in the combustion chambers of retort settings. But the gas engineer of to-day is not satisfied with such a temperature, for carbonising at such temperatures is too slow, and it would necessitate expensive building of new plant to meet the normal increase in gas sales. In working retort settings the author has proved to his own satisfaction, that a small percentage increase in the temperature of carbonisation will allow of a substantial percentage increase in the quantity of coal carbonised in a given time.

In the author's experience, a temperature of 1,280°C. in the combustion chamber of a retort setting is sufficient to carbonise a 10½ cwt. charge of coal in a 20 feet retort in 12 hours. By increasing this temperature to 1,320°C. the same charge can be carbonised in 10 hours, and by a further increase to 1,400°C., the period can be reduced to 8 hours. That 50 per cent. more coal can be carbonised in a given time by increasing the temperature less than 10 per cent. would seem to be impossible ; and, consequently, the author was particularly interested in the figures which Mr. A. H. Middleton included in his Paper on "Silica Bricks for Coke Ovens," (*vide* p. 169) which he read at the Birmingham Meeting of the Refractory Materials Section of the Ceramic Society. In this Paper, Mr. Middleton

recounted a similar experience of a very largely increased quantity of coal carbonised in coke ovens as the result of quite a small percentage increase in temperature. This being so, it must be expected that all the more enlightened gas engineers will be—if they are not already doing so—specifying material for retorts and for the supporting cross walls, which is capable of withstanding, with the minimum possible expansion or contraction, temperatures ranging from 1,350° to 1,400°C. under loads as experienced in retort settings. An expansion or contraction of over 1 per cent. from its original size when built, would be calculated to disturb the level of the retorts,and, therefore, this figure should be considered as the maximum to be allowed.

That material for retorts and the supporting walls should be expected to withstand such temperatures as 1,350 to 1,400°C. for longer periods than existing material, while not expanding or contracting more than 1 per cent. when used for and maintained at such temperatures, must seem very onerous and difficult of achievement. A few makers, however, are producing material which would appear to be able to live up to such requirements, and further, it is material which is capable of giving a much longer life than the 1,000 working days mentioned above. Therefore, the gain is twofold, while the duty obtained in tons of coal carbonised per retort life is much increased. The temperatures named, viz., 1,350–1,400°C. are low if the refractory material is to be used with no load placed upon it, but it is quite another matter when the load may be anything up to or even above 50 lbs. pressure per sq. inch. Such loads enormously increase the strain under which fireclay material has to do its work, though it is well known that loads have far less effect on high silica or even highly siliceous materials. It is probably true that at the present time not 10 per cent. of the coal carbonised is being dealt with in settings heated to such temperatures, but it is certainly true that far more coal would be carbonised at these high temperatures were the refractory material available to enable such temperatures to be safely employed.

The author visited America three years ago, and found all the gas works and coke oven works which he visited, numbering some 20 in all, were using such temperatures and were carbonising at a much greater speed than that to which we are accustomed in this country. But all the material used was high-percentage silica material. It might be said, why not then at once adopt such material and obtain the great improvement experienced in America? The answer might well be that, in this country, there is a large quantity of clay, which, by natural or artificial measures, can be employed to produce refractory materials which have neither the disadvantages of fireclay nor of 95 per cent. silica material. This material, namely, semi-silica or siliceous, may even claim to be the happy medium between the two. Fireclay so frequently shows too much after-contraction and too ready a tendency to soften

under load, while 95 per cent. silica material as often shows too much after-expansion, thus compelling the necessity of building in mill-board, wooden strips, or of leaving spaces in the setting. Further disadvantages of 95 per cent. silica material are that retorts have to be built up instead of moulded—an expensive alternative—while the tendency of the material to "spall" is objectionable. In the author's opinion, there is great scope for the production of a much larger quantity of semi-silica or siliceous material having a silica-content varying from 76 to 92 per cent. according to the position in the setting and the purpose for which it is required. The same class of material may also be used with great advantage for producer arches and walls, and for the crowns of the arches in horizontal retort settings.

Quite 75 per cent. of the material required for building modern retort settings should be of a quality having a maximum expansion or contraction at 1,350° to 1,400°C. under load, of not more than 1

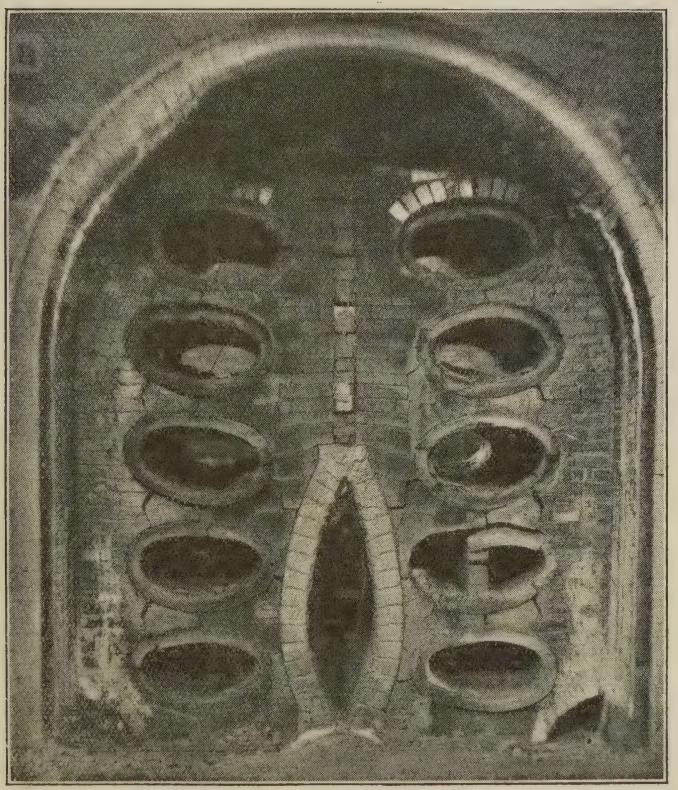


Fig. 6.

per cent. the remaining 25 per cent. being of a quality showing not more than 1 per cent. maximum expansion or contraction at 1,280°C. under load.

Figure 6 shows the effect of using materials which contract in

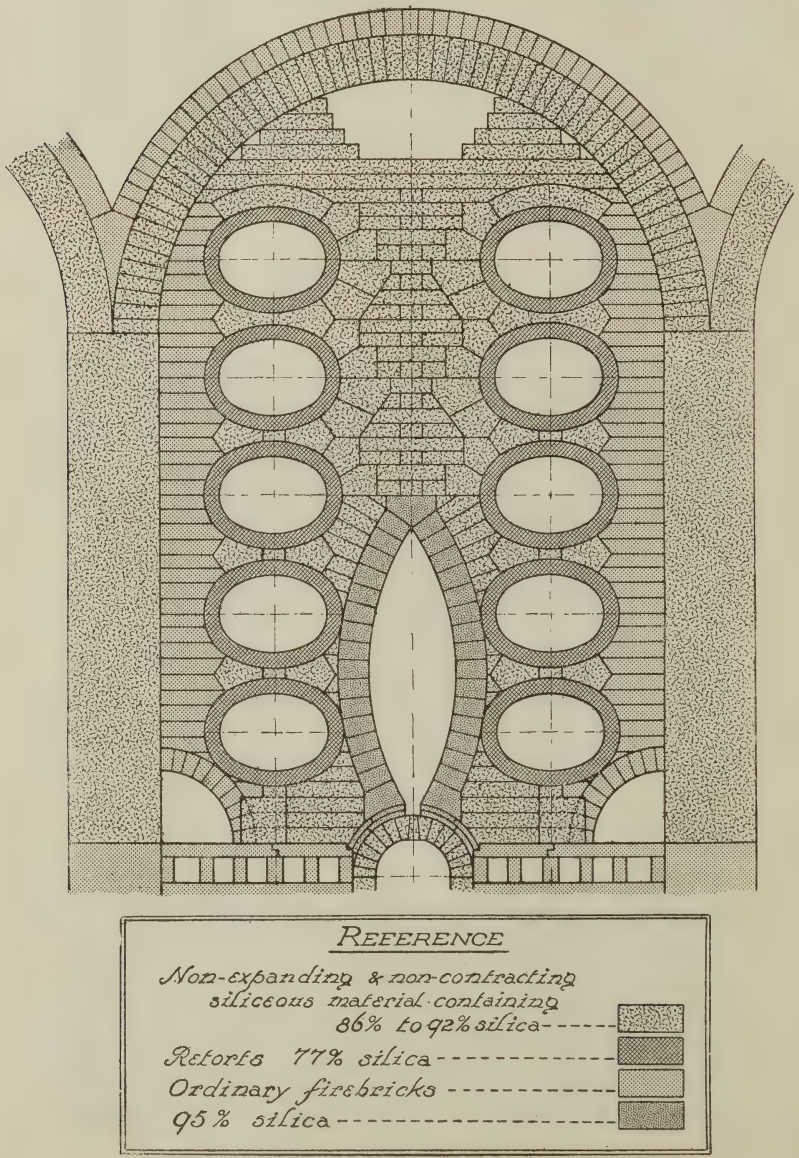


Fig. 7.

working. These retorts were originally set as shown in Figure 7, but owing to the combined effect of contraction and softening of the fireclay materials at the working temperature employed, the whole setting, with the exception of the silica combustion arch, sagged to such an extent as to be unworkable. This frequently happens in cases where unsuitable refractory materials are used.

Figure 7. shows one view of a type of setting designed and used largely by the South Metropolitan Gas Company. In this case suitable materials are chosen for their respective positions in the setting, one of the main objects being to use materials which expand or contract as little as possible, thus ensuring that the retorts shall remain level and true to shape and size throughout their life. This setting is suitable for high, but not for very high temperatures, for which purpose an all-silica setting must be employed.

Well-made 95 per cent. silica material of good quality should, in the author's opinion, be used in all cases for combustion chamber arches. He would here also state that the same material, if well and carefully manufactured of a uniform quality, and used for building retort settings with considerable knowledge and experience of its peculiar properties, can be employed to great advantage for such purpose. But this is a matter which really needs the combined knowledge and co-operation of manufacturer and retort setting designer and user, to produce the best results. The author deprecates the idea, sometimes put forward, that there is no special difficulty in building and working successfully retort settings of 95 per cent. silica material. All the difficulties can undoubtedly be surmounted so long as these are recognised and handled with experience, judgment, and intelligence. There will also be required for regenerator chambers a well-made, compressed material, without cracks of any sort, which can be safely used in pieces of 1 inch in thickness, for dividing waste gas from secondary air flues. As regards the quality of refractory materials offered to and used by gas undertakings, it has often been said that the cheapest tender secures the order, and that under such circumstances, there was no inducement for the manufacturer to improve the quality of his fire goods. There is no doubt that there is a good deal of truth in the statement of the lowest tenders being accepted, but every year, largely as a result of the work of such Associations as the Ceramic Society, there will be more who will employ a wise selection, and it is a sounder policy to manufacture a material which finds favour with the most expert buyers, rather than a material which sells only because it is cheap. This aspect of the question is certainly becoming more recognised by both manufacturers and users.

The author would here emphasize the essential importance of bricks being burnt to a temperature above that at which they will be used in a retort setting, and so obviate, to a large extent, the after-expansion or after-contraction which is otherwise likely to be experienced. There can be little doubt that bricks burnt at tem-

peratures higher than that to be employed in the combustion chambers of retort settings are more likely to give better results than those burnt at a lower temperature.

Another matter, which is deserving of continued consideration, is the question of standardizing the dimensions of firebricks and blocks, as expenditure on retort settings is materially increased by reason of the sorting and cutting of bricks which are necessary owing to the variations in the size of bricks and blocks. Much waste of time is thereby caused to the bricklayers building retort settings in picking out bricks of the same thickness to build into one course. If this trouble is not taken, as is sometimes the case, the alternative—a very objectionable one—of using a thicker joint is adopted by the bricklayer. Fire-brick work should always be built with the thinnest possible joint, and anything which is conducive to increasing the size of the joint, should be avoided. It is not

TABLE 1.

Showing the Maximum and Minimum Dimensions found by examining twenty-four Fire-bricks (of each of two well-known makers), chosen at random from a Stack of such Bricks. The Correct Dimensions should be $9 \times 4{\cdot}5 \times 3$ inches.

	Length	Breadth	Thickness
Maker (A)—	Inches	Inches	Inches
Maximum ..	9·30	4·56	3·16
Minimum ..	9·01	4·40	2·90
Difference ..	0·29	0·16	0·26
Maker (B)—			
Maximum ..	9·35	4·5	3·12
Minimum ..	8·92	4·27	2·87
Difference ..	0·43	0·23	0·25

unusual to find bricks from the same maker varying $\frac{1}{4}$ inch in length, width, or thickness. This points to variations in the details of manufacture, and leads one to assume that the causes of such variations may well be likely to affect in as great a degree the ability of such bricks to withstand temperature and other strains. That the dimensions of bricks do vary by the amount stated can be seen from Table 1, which the author has taken from a Paper which he read in January, 1922, before a Joint Meeting of the Institution of Mechanical Engineers and the Society of Chemical Industry.

In conclusion, the author would suggest that there is bound to be a growing demand for fire goods which bear the manufacturer's guarantee that their materials will, upon testing, withstand certain temperatures under definite loads, that the after expansion or contraction under stated conditions will be less than some definite amount, and that the dimensions will vary only between certain stated percentages. This, in the author's opinion, is the step which should be taken by those manufacturers who intend to

provide the gas engineer with what he will be requiring in substantially increasing quantities in the near future.

DISCUSSION.

Mr. C. A. King (Communicated):—This paper chiefly emphasizes the necessity for co-operation between the manufacturer of clay goods and the user.

The gas industry has been faced with more economic production, and in recent years the temperature of carbonisation has been increased. On the other hand, the refractory material manufacturer has clay only as his chief material in bulk, and although its fusibility may be recorded as 1,700°C. (cone 31-32) there are few clays which will withstand a temperature above 1,400°C. under works conditions, especially when in hollow built work and subjected to a reducing atmosphere. The only material available commercially for use at such temperatures is silica, and although trouble is generally experienced owing to the latent after-expansion of unconverted quartz, Houldsworth and Cobb (Trans. **21**, 253, 1922.) record tests on a commercial brick consisting almost entirely of crystobalite and with no free quartz, which would show that this fault is eliminated. While appreciating the desire for material which will remain rigid under widely varying conditions of temperature (a theoretical impossibility), it would seem also desirable that the gas engineering industry should study carefully the design of the retort bench so as to relieve and support the retort as far as possible, and especially to reduce the number of special shapes required.

Mr. W. J. Gardner:—The applause with which Mr. Gill's paper has been received at once proves its popularity. The subject has been presented by a gentleman who has had a good deal of manufacturing experience, and his paper certainly lacks nothing in courage. I do not quite agree with Mr. Gill's remarks about 95 per cent. silica material, and as a matter of fact the lantern slides which he has presented would appear to demonstrate that the only material which really withstood the tests was the 95 per cent. silica. There are several gentlemen present who will well be able to defend the 95 per cent. silica material and I will therefore leave further discussion to them.

Mr. A. H. Middleton:—I have much pleasure in giving my testimony to the excellence of Mr. Gill's paper, and I would like to say how thoroughly I have enjoyed it. I think the accompanying of the paper by lantern slides a most useful feature, and I trust that Mr. Gill will see his way to have some of these diagrams published along with the paper, so that we may all have the benefit of a careful study of them at our leisure.

Mr. Gill's paper has brought very forcibly before us a thing that we have most of us realised, and one that is going to meet

Fig. 1.

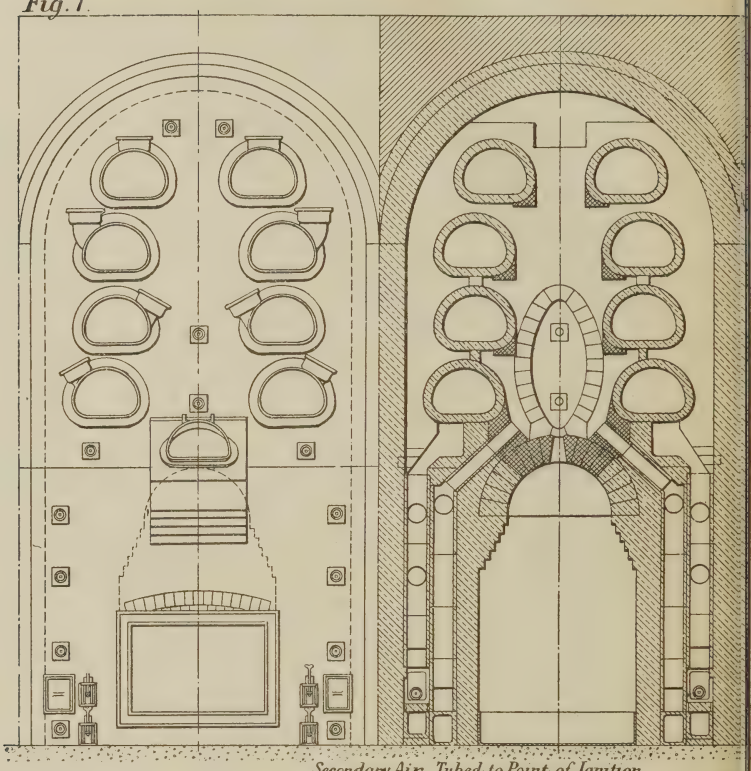
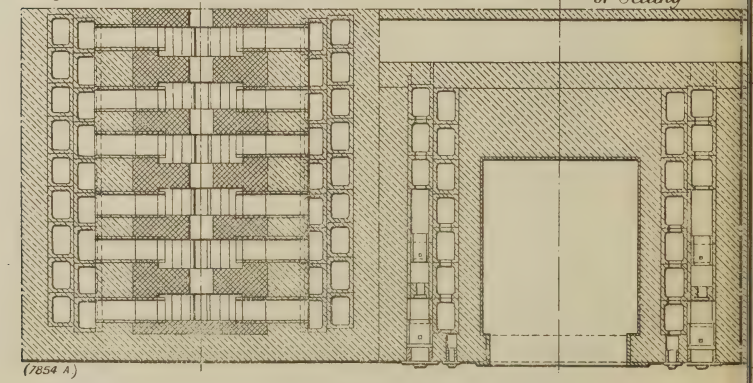
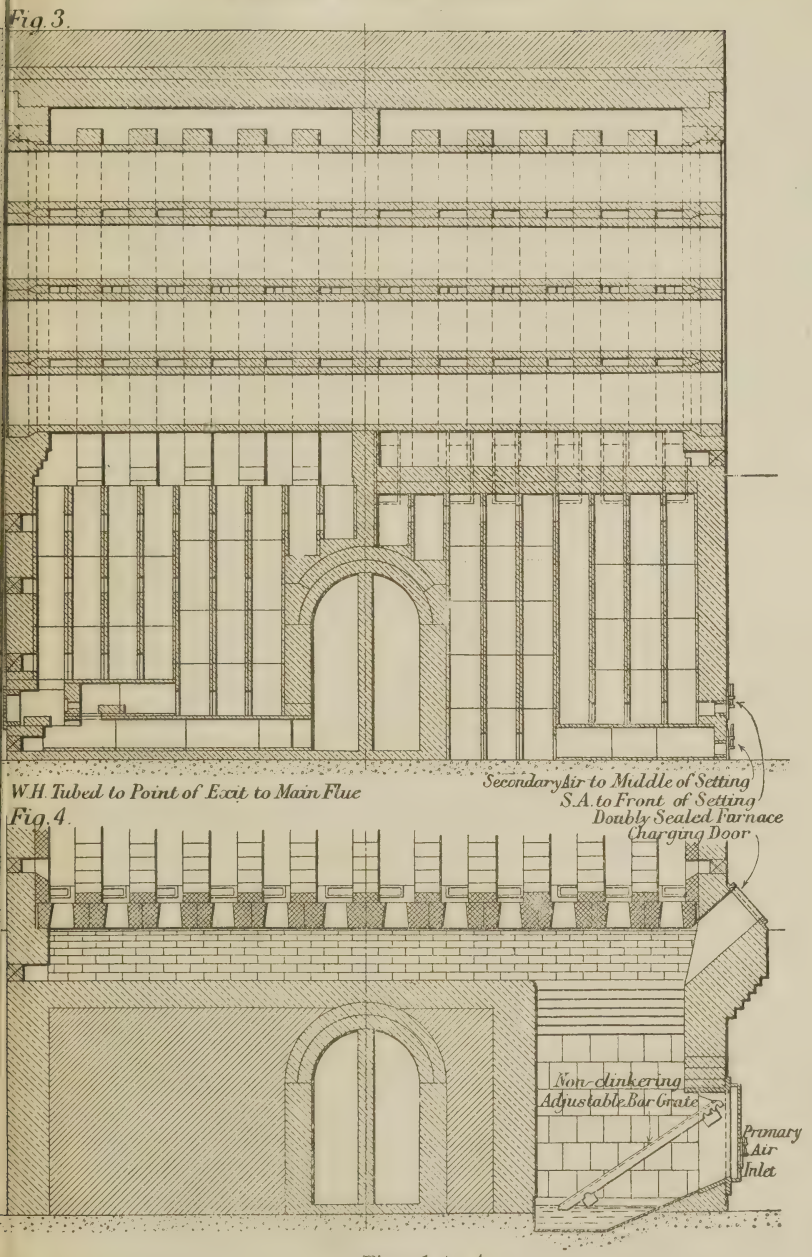


Fig. 2.



Figs. 1 to 4.
(For description see page 377).



Figs. 1 to 4.
(For description see page 377).

with general acceptance, viz:—the great necessity for co-operation between the manufacturer of a material and the user of it. The photographs which he has shown us, illustrating the failures of different classes of material in various parts of a retort setting bear out this point very fully, and prove that a good many of the difficulties could be overcome quite easily if there were closer co-operation. Without this co-operation, however, progress is practically impossible, because the brickmaker does not know exactly for what service his bricks are going to be used, or the positions in which they will be expected to work. I am inclined to think that the suggestions Mr Gill has advanced will prove to be of the utmost value. He has very clearly shown the necessity of having different materials in different parts of the setting. Many of us now realise that the conditions in one part of a gas setting are almost diametrically opposed to those of another part. A material that is quite suitable in one place will be quite unsuitable in another. To get the best results we shall apparently have to resort to the use of a series of different classes of material.

With regard to silica bricks, it is becoming recognised that they are quite holding their own, although there is certainly need for a good deal of work yet to be done before we know exactly the best way of using them. The question of millboard jointing, mentioned by Mr. Gill, and the various substitutes that have to be resorted to at present in order to nurse the expansion , will undoubtedly call for increasing attention by gas works engineers and silica brick makers alike, until a brick can be produced which will not require nursing in this way. I am very hopeful, however, that in a short time the silica brick manufacturers will be able to prove that this can be done. With regard to the different thicknesses of bricks, to which Mr. Gill has alluded in his paper, this is certainly a point of some importance. Certain undertakings are now endeavouring to get the gas engineers to adopt as far as possible some sort of standard designs, so that not every enquiry which a brickmaker handles will necessitate the making of a different set of moulds. If there can be some standardization on these lines it will certainly be very useful. In gas works the complications are bad enough, but in coke oven works they are worse still. For one particular type of oven over 300 different moulds are required to make the bricks and blocks, and besides this, the moulds of individual makers generally vary. It would be very useful if the gas makers would put their heads together and endeavour to eliminate some of the complications.

Mr. H. J. C. Johnston:—When Mr. Gill read a paper in January, 1922, before a joint meeting of the Institution of Mechanical Engineers and the Society of Chemical Industry, he had some very hard things indeed to say about the manufacturers of refractory materials for gas works. It is very pleasant, therefore, to be able to notice that his present attitude is one of advice rather

than of reproof. The points which he has made in his paper are of the greatest importance to the manufacturers of retorts and bricks for gasworks. In particular, the remark which he has made on the question of the cheapest tender may be regarded as timely and justified. It is very disheartening indeed for a manufacturer, whether he is engaged in the silica or the firebrick trade, to find that, after spending a great deal of time and money upon experiments, the gas managers and gas companies are unwilling to pay the extra price for the extra life and advantages which they may obtain. With regard to the question of the standardisation of shapes and sizes, I would like to suggest that it would be conferring a great service upon the manufacturers of retorts and bricks if something could really be done to arrive at this standardization. As anyone who has had anything to do with the gasworks trade knows, the bolt holes in practically every retort in every gasworks throughout the country are different. This, of itself, suggests the urgent need for standardisation. At the same time I would cordially endorse the suggested standardisation in regard to the dimensions of fire-bricks and blocks. I have long advocated that something should be done in this country on the lines of what has already been done in America by the American Refractories Association. There they have a standard price for bricks of standard sizes and a higher price for bricks required of different dimensions.

I am not going to enter into any controversy with the Chairman or Mr. Middleton on the question of silica *versus* fireclay. For my own part, I think that Mr. Gill has dealt with that question very fairly, for he has given his meed of praise—perhaps more than it deserved—to the use of silica in gasworks, but he has also given us his considered judgment—and after what we have heard during the past few years in the Ceramic Society, it is very refreshing to have that considered judgment—that the best material is the siliceous material. And in giving that wide scope of silica content from 76 to 92 per cent., I think Mr. Gill has acted very wisely. My view is that the silica content is of minor importance, and that too much stress has been laid in the past on the question of analysis with regard to materials required for such purposes as in gasworks. The test of temperature resistance under load, and above all the practical test of the life of a material in work, is of very much greater importance, to my mind, than the question of chemical analysis. I would like to join with the earlier speakers in thanking Mr. Gill for what I regard as a very valuable paper.

Mr. Philip G. Moon:—I much appreciate the opportunity of saying a few words on a subject in which I am keenly interested. I have listened with great interest to Mr. Gill's paper, and needless to say, it has raised certain points in my mind. I am very glad to see that Mr. Gill has laid emphasis upon the importance of considering the pressure that firebrick has to withstand in a retort setting, as well as the temperature. From this point of view I

endorse very heartily the remarks of Mr. Johnston that, whilst chemical analysis would give one some useful information, the point which counts most of all is the behaviour of a fireclay material under *temperature and pressure*, and during a reasonable run of practical working. At Bournemouth vertical retorts are largely used, due, to some extent no doubt, to the association with the Bournemouth undertaking of Sir Arthur Duckham and Sir Wm. Jones. Having been pioneers in the vertical retort industry, we suffered at Bournemouth in the early days very considerably through the failure of the refractory materials with which we were supplied. We had materials which would stand up under horizontal conditions very well, but when, instead of having a superincumbent load of 10 ft. or so of fairly light material, with plenty of spaces between the material, we came to have 25 ft. or thereabouts of very close material, with heavy castings on the top, we discovered that the firebrick material hitherto used failed lamentably to stand up under the pressure. A new factor has been introduced, viz:—pressure, and this, in combination with the temperature, brings serious difficulties. Since those early days very considerable improvements have been made in the manufacture of refractory materials, and now we are able to get materials—largely siliceous in the higher temperature zone, and more on the fireclay side in the less heated zones—which will withstand all the pressure. But even now we are suffering rather considerably through the expansion of silica material where we, get the disabilities due to the higher expansion coefficients. We found that the expansion coefficient could be divided broadly into two characteristic classes, viz:—the permanent expansion, which we ought to expect the refractory materials manufacturers to take care of by adequately firing their products; and the reversible expansion with which it is more difficult to deal, and for which the gas engineers have themselves to provide at the present time by the insertion of millboard joints, which burn away and leave room for the expansion of the silica material as the temperature rises. But I think that both manufacturers and users can say definitely that excellent progress has been made of late years in the direction of producing a very much higher class of refractory material, and from the users' side I would not hesitate to say that this improvement has largely been brought about as the result of the work that has been done by the Ceramic Society, through the medium of the Refractory Materials Section.

Mr. Fagan:—I have listened with great interest to Mr. Gill's paper, and I would recommend that his advice be taken by the gas engineers as well as by the manufacturers of bricks for gas works' use. It appears to me that by careful selection from the various sources of supply at present open to them the gas engineers can satisfy all their requirements. As I understand it, Mr. Gill is of the opinion that 95 per cent. silica material is the best to employ

for combustion chambers, but that siliceous material should be used in certain parts of the setting, and ordinary firebricks in others. If the gas engineers will take notice of this advice, I feel sure it will be to their advantage, as well as to the advantage of the brick manufacturers. There is one other point that requires clear emphasis, and that is, that the materials generally should be burned to a higher temperature than that at which they are intended to be used. I believe that the manufacturers, as a general rule, are now following this idea, and it will certainly do much to avoid a good deal of the contraction and expansion that has hitherto been experienced and that has greatly troubled gas engineers in the past.

Mr. F. C. Brooke:—I would like to back up Mr. Johnston as regards the advisability of standardising shapes and sizes. I believe that Mr. Gill can himself do more with the gas engineers in this matter than anyone else, because he knows their requirements so intimately. If something could be done to arrive at something like standardisation it would be a great boon to the fireclay industry; it might even enable the manufacturers to sell at a lower price than at present. The prices at present are perforce high, as a result of the enormous cost to which the manufacturers are put in the making of innumerable moulds, and the consequent employment of a staff of engineers and joiners.

Mr. Ackermann:—Amongst the slides which Mr. Gill has presented I noticed some retorts that are obviously oval and placed with the major axis of the oval horizontal. There may be definite reasons why these retorts are so placed, but from a constructional point of view I should like to see these retorts placed with the major axis vertical, by which means they would be capable of withstanding about four times the present load.

The next point which occurs to me is the question of fuel economy. I recently went to a large London gasworks and I can assure you that to me it was perfectly heart-rending to see the waste of heat which was going on. Some of the waste heat was used in a regenerative way, but this was but a mere fleabite to the amount of heat that was being wasted. It would almost seem as though we ought to have our big electricity supply undertakings built practically on the top of our gas stations if we are to economise heat. After the temperature at the bottom of the chimney has been attained the rest of the heat seems to be entirely wasted.

The third point which occurs to me is, that I cannot help thinking it will be found that just as the pressure fluidity of clay varies with the quantity of water, so with every different high temperature fire-bricks will have a different pressure fluidity. I merely put this forward at the moment as a suggestion, for it will have to be proved, but it seems to me that we shall discover that the higher the temperature the lower the pressure fluidity. This means that it will be necessary to work within temperatures which avoid the critical points.

MR. GILL:—I am quite satisfied with the discussion my paper has promoted, and I much appreciate the kind remarks made by the speakers. I am afraid Mr. Gardner has rather misunderstood me about the 95 per cent. silica material. I did not wish to condemn it; on the contrary, I think there is a very great future for it. When I was in America I was greatly impressed with the results that are being obtained from its use. The only point that I did not like was the greatly increased complication in the building-up of retort settings. The point that I wanted to make was that, if we could employ something that does not necessitate the provision of millboard joints between the bricks and blocks, it would be possibly more attractive. Whilst I feel that high percentage silica material has a great scope, as well as the semi-siliceous material, I think it is highly important that manufacturers and users should pool their knowledge in order that really good retort settings should be forthcoming. With Dr. Mellor's permission I should be very glad to include the illustrations in the publication of my paper, in accordance with Mr. Middleton's suggestion. With regard to the bolt holes in retorts, it is quite true, as Mr. Johnston has stated, that these differ considerably. My own opinion is that it is rather out of date to use bolt holes in retorts at all. The retorts ought to be made with a flat end, so that an iron socket could be placed over the end and the holes bored in the iron socket. This is a much improved method of joining the mouthpiece to the retort. I would have liked to have gone carefully into some of the points that were raised by Mr. Moon, because with vertical retorts the problems are very different. There is a very considerably increased load on a good deal of the material used in vertical as compared with horizontal retorts, and when the material expands it entails loads the full effect of which it is difficult to calculate. I am interested to hear from Mr. Brooke that there is a possibility that if the sizes of firebricks and blocks were standardised the prices might be reduced. That, certainly, should be likely to appeal with special force to the management of some gas undertakings.

XXXI.—The Specific Heat of Magnesite Brick at High Temperatures.*

Communication from the Clay and Pottery Laboratory, Stoke-on-Trent. No. 103.

By A. T. Green.

Introduction.

A certain determination of the thermal conductivity[1] of magnesite brick involved a knowledge of the specific heat of this material at high temperatures. Such data are very scanty. Heyn, Bauer, and Wetzel[2], however, have reported values of this "constant" up to 1,200°C. Since the composition of the material used by these investigators was somewhat different from that of the material used in the above-mentioned experiments on thermal conductivity, it was thought advisable to repeat the work before using the data.

While these determinations were in progress, the investigations of Yoshiaki Tadokoro[3], which include the evaluation of the mean specific heat of magnesite up to 900°C., came to hand. The values of the "constant" given in this report agree fairly well up to 600°C. with those of Heyn, Bauer and Wetzel. Above this temperature, however, there is no agreement, Tadokoro noting a small decrease in the specific heat with rise of temperature. The present work, therefore, may serve to define an opinion on the relation between the specific heat of calcined magnesite and temperature.

Apparatus and Method.

Bradshaw and Emery[4], who investigated the specific heat of silica, fireclay and zirconia, have given a detailed description of the identical apparatus and method used in the present work. The reader is referred to their paper.

With a view to completing the present paper a brief account of the method is given below.

A cylindrical testpiece ($2\frac{3}{4}$" long and $1\frac{3}{4}$" diam.) weighing about 300 grms. and supported at the bottom by means of four hollow cups (made from a mixture of china clay and alumina) is placed in the carborundum inner tube of a specially-fitted Hirsch furnace and secured in position. A thermo-couple, previously calibrated, is placed in a hole drilled down the middle of the test-piece and held in position at the top of the furnace. The apparatus is so arranged that the test-piece and supports, after being heated to a required temperature, can be quickly dropped into water contained in a rectangular, iron tank. This tank, which is

*We are indebted to the British Refractories Research Association for permission to publish this paper.

suitably insulated, has a capacity of about 50 litres. The water can be stirred by means of two stirrers driven by a small electric motor. The splash-breaking apparatus, devised by Bradshaw and Emery, is used to eliminate loss of water and the formation of

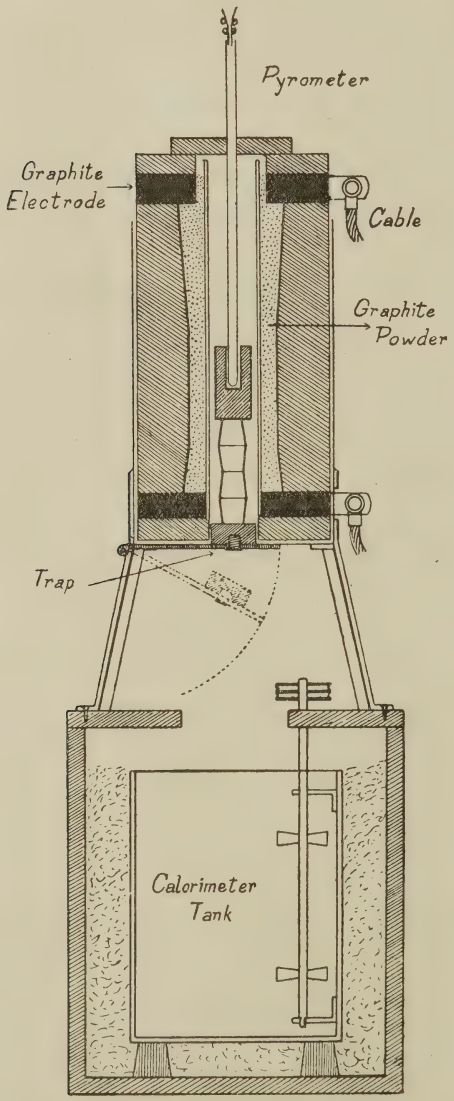


Fig. 1—Calorimeter and Electric Furnace after F. Glaser.

steam, when the test-piece and supports are dropped from the furnace. A Beckmann thermometer, reading to 0·005°C., measures the rise of temperarure after the immersion of the heated test-piece and supports.

In the experiment, the piece set on its supports is slowly raised to the required temperature, which is kept constant for about half-an-hour. Half-minute temperature readings of the known volume of water in the calorimeter are taken with the Beckmann thermometer, for five minutes before the immersion. The actual temperature of this water is measured by means of another thermometer. After the immersion of the test piece and supports the rate of rise of the temperature of the water is obtained in terms of half-minute readings over a period of twenty minutes. Following each such determination a black experiment is carried out in order to obtain a correction for the supports. A cooling (or heating) correction is applied to each determination. The water equivalent of the calorimeter is found by taking the mean of several separate experiments to be equal to 1,550 grms. of water.

The results are computed from the above determinations by the usual method.

Results.

The results tabulated below represent the mean of five determinations. Thus the values of determinations at 1,115°C. are 0·295, 0·287, 0·293 and 0·291. The mean value taken is 0·292. For purposes of comparison, values of the "constant" deduced from the figures reported by Heyn, Bauer and Wetzel and Tadokoro, are appended.

TABLE I—Mean Specific Heat between 25°C. and θ°C.

Temp. θ°C.	Present Investigator	Heyn, Bauer & Wetzel	Tadokoro
200°C.	—	—	0·220
400·C.	—	0·258	0·256
605·C.	0·265	0·267	0·266
825·C.	0·274	0·277	0·264
930·C.	0·280	0·281	0·264
1040·C.	0·285	0·285	—
1115·C.	0·292	0·289	—

TABLE II.—Percentage Analyses of the Magnesite Materials.

	Present Investigator	Heyn, Bauer & Wetzel	Tadokoro
SiO_2	2·34	0·20	18·26
Al_2O_3	n.d.	0·17	0·56
Fe_2O_3	2·56	9·31	0·80
CaO	4·68	0·35	Trace
MgO	87·88	88·85	76·43

Discussion of Results.

The results of the present investigation agree quite well with those reported by Heyn, Bauer & Wetzel. Nevertheless, owing to the difference in the amounts of Fe_2O_3 and CaO present in the respective materials used by the latter investigators and the author, some disparity might have been anticipated.

In comparing our results with those of Tadokoro, it is well again to note the great difference in the composition of the materials of experiment. This fact, however, does not seem to explain the decrease in the value of the constant with increase in temperature over 600°C. Besides investigating magnesite material, Tadokoro included fireclay, silica, chrome and other materials in his scheme. In all cases, the mean specific heat increases with temperatire up to about 600°C. and then slowly decreases from this temperature to 1,000°C. Bradshaw and Emery, and Heyn, Bauer and Wetzel observed no such maximum value in their work on silica and fireclay material. The former investigators obtained an almost linear increase in the value of the mean specific heat with temperature. It should be mentioned that, for his determinations, Tadokoro used 3 grams of material enclosed in a platinum casket. The calorimeter contained 300 ccs. of water. This is in marked contrast with the 300 grams of material and the 45 litres of water used by the present investigator.

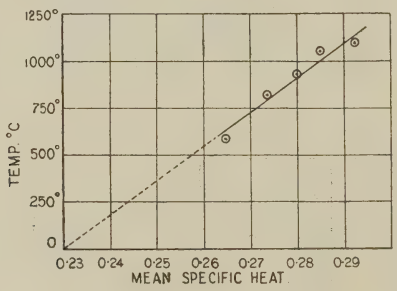


Fig. 2.

RELATION BETWEEN SPECIFIC HEAT AND TEMPERATURE.

The curve (Fig. 2) suggests that the mean specific heat of calcined magnesite increases linearly with temperature. Assuming that the value of the constant at 25°C. is 0·232, which fact is indicated by the curve, we observe that the mean specific heat between a temperature θ°C. and 25°C. is given by the equation:

$$\text{Mean Specific Heat} = 0{\cdot}232 + 0{\cdot}000052\ (\theta - 25).$$

The value 0·232 for the specific heat at 25°C. agrees with reported values for samples of pure magnesia. Russell[5] gives 0·2385 for the pure substance at 25°C.: Steger[6], for a similar material

(98% MgO) gives 0·246 as the mean specific heat between 25°—205°C. and 0·264 between 25°—405°C. The last-named investigator[7] also gives 0·225 as the mean specific heat between 0° and 200°C. of a magnesite material, containing 84·5% MgO. This value seems slightly low.

TABLE III.—Actual Values of Specific Heat of Magnesite Brick at Definite Temperatures.

Temperature	100°C	200°C	400°C	600°C	800°C	1000°C	1100°C
Specific Heat	0·239	0·250	0·271	0·293	0·313	0·334	0·345

Since it is often desirable to know the value of the "constant" at a specific temperature, Table III is appended. The linear law is assumed to hold good from 25° to 1,100°C. in order to allow the computation of these data.

In conclusion, the author expresses his thanks to Miss D. A. Jones, B.Sc., for valuable assistance in the early stages of the experimental work.

References.

(1) Green, Trans., **21**, 406, 1921-22.

(2) Heyn, Bauer & Wetzel, *Mitteil. königl. Material-prüfungsamt*, **33**, 89, 1914; *Sprech.*, **52**, 499-501, 1919.

(3) Tadokoro, *Science Rep. Tohôku Imp. Univ.*, **5**, 5,1921.

(4) Bradshaw & Emery, Trans., **19**, 84-92, 1919-20.

(5) Russell, *Phys. Zeit.*, **13**, 59, 1912.

(6) Steger, *Silikat-Zeit.*, **2**, 54, 1914.

(7) Steger, *Silikat-Zeit.*, **2**, 204, 1914.

XXXII.—On the Behaviour of Kaolin on Heating.

By W. J. Vernadsky.

In a recent paper, Messrs. Houldsworth and Cobb give some new data on the behaviour of kaolin on heating. Unfortunately, the authors selected for their work a kaolin which was not pure, but contained a certain amount of undetermined admixtures, as can be seen from their analysis. Hence it is possible that some of their critical points are not connected with the behaviour of kaolin, but with some of the admixed substances (mica, hydromicas, or zeolithoids). The general phenomena, however, undoubtedly refer to kaolin, since they agree with observations made by previous investigators, some of whom worked with very pure material. The authors do not give any theory of their results, but refer to previous explanations. As I cannot find among the latter one which corresponds with the facts, which I and other workers have observed, I propose to discuss the results in the present paper.

Chemically, kaolin is an alumino-silicic acid of a very peculiar character. It contains two molecules of water but only one of these (equivalent to two hydroxyradicles) can be replaced by metals, either synthetically or in reactions occurring in nature. The formula for kaolin :—

$$2H_2OAl_2O_32SiO_2$$

must therefore be written

$$H_2Al_2Si_2O_8H_2O$$

in order to agree with these chemical facts.

The peculiar character of kaolin water has only recently been detected on the basis of the behaviour of kaolin under heat treatment. The lack of suitable methods of experiment have hitherto prevented any exact determination of the temperature at which kaolin loses all its water. In the experiments of Messrs. Houldsworth and Cobb, the critical point (420-450°C.), obtained by noting the temperature at which a sudden decrease in weight occurs, does not correspond with the temperature—500-530°C.—obtained from thermal analysis. The difference in the character of the two molecules of water in kaolin is based on the chemical properties of the substance. It is possible that the second water molecule, which does not enter into the constitution of the acid $H_2Al_2Si_2O_8$ (kaolinic acid), has some of the properties of water in solution. The molecule will, on this hypothesis, evaporate at a definite temperature (above 400°C.), according to the partial pressure of water vapour in its environment.

The loss of water on heating is certainly accompanied by an absorption of heat and by a change in the chemical properties of the substance. From many investigations, *e.g.*, those of P. Zemjatchensky, A. Sokolov, V. Itküll, and others, we know that, on heating to a temperature of 450-500°C., the previously insoluble kaolin becomes easily decomposed by acids, particularly by hydrochloric acid. The properties of the alumina and silica extracted in this way are the same as in kaolin, while, according to P. Zemjatchensky, the residue $Al_2Si_2O_7$ is also soluble. Many theories have been published regarding the constitution of this hydroxide mineral, but these do not generally agree with the peculiar chemical functions and structure of the substance. After the water has been driven off the kaolin becomes an anhydride, $Al_2Si_2O_7$. Until recently, no substance corresponding to this anhydride was known in nature, but a short time ago E. Wherry and T. Larson showed that the mineral, long ago described by P. Termier and called leverrierite, can be considered as $Al_2Si_2O_7Aq$. The water which this compound contains is labile and is driven off at a temperature below 300°C. Incidentally it may be noted that leverrierite does not correspond exactly with this formula, as it often contains small quantities of iron oxide, lime, and potassium oxide. E. Wherry and T. Larsen had not considered the possible relationship of these substances to kaolin, or to any type of clay, but rather endeavoured to establish the independence of the leverrierite group. This group of minerals seems to belong to a type which corresponds with anhydrides of kaolinic and similar acids, all containing labile molecules of water. The results of the above investigations, together with those of Cayeux, Termier, and Wherry, can be taken as indicating that this group of minerals enters into the composition of clays, or analogous compounds, to an extent which was not previously suspected. Hence it is very probable that the leverrierite group may commonly occur in surface minerals.

From the behaviour of the dehydrated kaolin with regard to acids, we must assume that the transformation from that substance to leverrierite can be expressed by the following scheme :—

Kaolin	420-530°C.	leverrierite
$H_2Al_2Si_2O_8.H_2O$	heat absorption	$Al_2Si_2O_7$.

The critical point, observed on the shrinkage curves, corresponds to polymorphic changes in leverrierite. For example, it is known that, on heating kaolin to a temperature somewhat higher than that at which the water is lost, a residue, insoluble in acid, is obtained, and this change to insoluble residue may correspond with one of the critical points on the shrinkage curve. The critical point (930-950°C.) is accompanied by an evolution of heat and this fact, which was described by H. le Châtelier, is of greater interest theoretically. It probably indicates a fundamental change in the structure of the mineral, and it may be an advantage to discuss it in some detail.

The chief characteristic of the mineral group to which kaolin belongs is, that it contains a complex, $Al_2Si_2O_7$, generally in the form of $M'_2Al_2Si_2O_8$ or $M''Al_2Si_2O_8$ (a kaolin nucleus) which remains unchanged throughout a number of chemical reactions. All the minerals of this group produce clays of kaolinic structure in the weathering zone of the earth's crust and can be obtained synthetically from kaolin. When these substances, either in nature or in the laboratory, are transformed one into another, this kaolinic (or, as I previously termed it, muscovitic) nucleus ($M'_2Al_2Si_2O_8$ or $M''Al_2Si_2O_8$) remains unchanged. The commonest minerals—felspars, micas, garnets, epidotes, nephelines, leucite, scapolites, zeolites, etc., belong to this group of alumino silicates. During the various transformations, one into another, which these minerals are constantly undergoing under both plutonic and surface conditions, the radical $Al_2Si_2O_7$ remains unchanged and hence must be regarded as a very stable group of elements.

Amongst many thousands of chemical reactions, both in the laboratory and in nature, there is none known in which the linkage between alumina and the silicon atoms of kaolin can be broken at a low temperature. The case where this linkage is broken at a low temperature, in the formation of laterite, occurs under peculiar conditions and is analogous to a biochemical process. All other chemical changes, which the aluminosilicate undergoes in the earth's crust, are effected without either the destruction or the synthesis of the kaolinic nucleus; it is, however, destroyed under certain secondary volcanic processes by the action of acid gases and also under superficial conditions by the action of strong acids in a free condition at low temperatures. In the earth's crust the synthesis of this nucleus goes on only at high temperatures, both under magmatic conditions and by hydrothermal processes. The same is true of laboratory work, in which the synthesis can only proceed in aqueous solutions at temperatures higher than 200-300°C. under considerable pressure or in fused silicates. In every case the thermal effect is considerable. All we know about the thermal history of the formation of the kaolinic nucleus is that the nuclei $M'_2Al_2Si_2O_8$ or $M''Al_2Si_2O_8$ correspond to endothermic compounds and that all the alumino-silicates of the kaolinic structure are formed with the absorption of heat.

It is very improbable, in view of our present knowledge of alumino-silicates, that kaolin can be decomposed into alumino-silicates (or other compounds) at such a low temperature as 420-450°C., without a strong thermal effect, such as the heat absorption which is necessary to expel the chemically combined water. P. Zemjatchensky showed not long ago the non-existance of a free silica or free alumina in the residue obtained at this temperature. The decomposition of the remaining kaolin ($Al_2Si_2O_7$, leverrierite) occurs at a high temperature (920-950°C.) with the evolution of heat, and it represents the second critical point on

the heating-curve of kaolin as described by H. le Châtelier. This destruction of leverrierite does not give rise directly to sillimanite. It is a complex process, which is not very well known, and the crystals which are formed in it generally contain (certainly at the commencement of the reaction) more alumina than is required by the formula for sillimanite Al_2SiO_5. The most important thermal effect, however, is the breaking down of the kaolinic nucleus. The destruction at high temperatures of this nucleus can be observed in many processes in natural rocks—*e.g.*, in the formation of sillimanite and melilite in massive rocks—and also in synthetic work. If, however, potassium be present, then at temperatures above 1,000°C. salts of a sillimanite nature ($K_2Al_2SiO_6$) are formed and at lower temperatures salts analogous to leverrierite (*e.g.* $K_2Al_2Si_2O_8$), as was shown by S. Weyberg.

Summary.

1. By the loss of water kaolin forms an anhydride, $Al_2Si_2O_7$—leverrierite. This process is accompanied by the absorption of heat at a temperature between 420-530°C.
2. The critical point on the heating-curves observed at high temperatures probably corresponds to polymorphic changes in the compound $Al_2Si_2O_7$.
3. The exothermic reaction at 930-950°C. discovered by H. le Châtelier, corresponds to the destruction of the kaolinic nucleus, which must, therefore, be regarded as an endothermic compound.
4. The destruction of this nucleus is a complex process in which occurs the gradual setting free of the molecules of silica from the compound $(Al_2Si_2O_7)^n$.

DISCUSSION.

Dr. J. W. Mellor (communicated):—The note in the Transactions, **22**, 105, 1923, seems to have stimulated Prof. Vernadsky and Prof. Rebuffat (*Boll. Ceramica Vetro.*, **4**, 1, 1922) to object to the hypothesis there indicated. I suppose that some kind of reply from me is expected. All I have to say at present has been said in several papers in the Transactions published in 1909 and subsequent years. This work has been since confirmed by numerous workers. The latest are G. Tammann and W. J. Pape (*Zeit. anorg. Chem.*, **127**, 43, 1923); and S. Satoh (*Science Rep. Tohoku Univ.*, (3) **1**, 157, 1923). Until the evidence there accumulated has been answered, a flaw shown in the reasoning, or new evidence brought forward, I do not see that any useful purpose is served by repetition. Neither of the gentlemen named has done any one of these things; their hypotheses do not cover the known facts.

XXXIII.—President's Address.

By H. E. Wood.

IT was my intention to have prepared for you a paper on a special subject, and at the beginning of my year of office I started on a series of trials which should have been followed up, but, unfortunately, those trials have not been completed, and the paper must stand over to some future date.

The Session has not been an uninteresting one. As you know, the year commenced with what is regarded as the Society's most successful tour. The visit to Scandinavia was a brilliant success, not only socially, but also educationally. Anyone who was able to make the trip and had his eyes open saw much worth noting and considering. I do not mean to infer that there was much that we should adopt outright, with a scrapping of our own methods; conditions in the various countries are too diverse for that to be likely, but we saw variations in methods which made us consider why this was done, and that, in my opinion, is the main advantage of trips such as this.

What impressed me most of all was the practically unlimited water power, which was gradually being harnessed to electricity, giving cheap power in all parts of the country at prices which to us here seem incredible. But those who had the privilege to go will remember that at Höganas we saw gas for firing and electricity being produced cheaply from fuel, which closely resembled the stuff picked from the waste heaps during the coa strike here. If ever things become normal again, there should be a useful lead here. The days when North Staffordshire was said to owe its pottery trade to cheap coal are certainly past, and at the present time, I do not think there is much material being thrown away which might be used; it is loaded up along with the rest. If the time comes, however, when fuel is picked once more, this inferior stuff should most certainly be used here on the spot where railway rates do not apply.

Another impression I had was that our Scandinavian friends do not cramp themselves in their factories; there was, generally speaking, a reserve of space which we rarely find here. This may be largely due to the age of many of our factories, and when we criticise in this way it is well to remember that probably the design was quite good for the conditions of the times; but requirements now are in many cases vastly different.

I ought also to mention the pleasure afforded the Society in being able to entertain Mr. and Mrs. Odelberg here in England, and to give them some tangible recognition of their kindness to us.

During the Session we have had an interesting series of papers covering a wide range of subjects, commencing with Mr. Odelberg's account of his continuous flint grinding, which is worth careful study. I should like to make a special mention of the night spent with "Josiah Wedgwood's Note Books." I found it deeply interesting to read of his troubles and difficulties. In some respects they are very similar, in others dissimilar from ours to-day. Some of our improvements have brought new difficulties in their train. Take the question of iron, for instance. I presume he would blunge with a wooden paddle and dry on a kiln, where now we have iron blungers, iron pipes, pumps, etc., and the materials often come in iron boats or trucks. I fancy, too, in Wedgwood's day, it was not impossible to open a window without getting everything in the shop covered with dust and dirt.

The papers presented have dealt with subjects of such varied character as to warrant a sustained interest in our meetings, yet I feel our attendances and the interest shown are not what they might be. One explanation is probably that many of the papers require digestion, and knowing that we shall get them in full in the "Transactions," which we can read comfortable at home, we are not so keen on coming to hear the paper read. In mentioning the "Transactions," I would like to emphasize their value, containing as they do all the lectures, many communicated papers and also the Abstracts from other Journals. In the old days we were very much handicapped by the want of literature, especially in English, as you will recognise, when I tell you that, when I was a student at the Pottery Classes, the only references were the article on Pottery from Spon's Encyclopædia and the catalogue of specimens (with a few historical notes) of the Jermyn Museum. Times are much changed and there is now no lack of English ceramic literature, (in the fore-front of which I place our own "Transactions"), and our translators keep us in touch with foreign literature. The trouble now is to keep pace in one's reading with the output.

I apologise for the time I have kept you, but my interest is in the success of the Society, and I congratulate you on the progress of the past year. I am wishful for more interest and larger attendances next Session. Before concluding, I should like to congratulate the Pottery Industry on the fact that, all through the trying years of war and the still more trying subsequent years of peace, it has managed to carry on without a strike or a lock-out. It has been a rather depressing year of trade, but I believe the corner has been turned and the improvement, although slow, will be a steady one.

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TRANSACTIONS

OF

THE CERAMIC SOCIETY

VOL. XXII.—1922-23.

ABSTRACTS.

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1923.

INTRODUCTION.

THE following are abstracts from papers bearing upon the clay, refractories, and glass industries in the more important foreign journals as well as those of our own country. The abstracts are arranged roughly in eight main classes. The groups are constantly overlapping, and, to avoid repetition, a copious index is appended. This will enable any reference to be quickly found. Most of the journals quoted are permanently filed so that the full papers may usually be consulted by members of the Society. Full translations of any of the foreign papers can be obtained at a small charge. As a rule the abstractor indicates the "subject title" of those articles which, in his opinion, contain either no original matter, or matter not suitable for abstraction. These abstracts were made possible by a grant from the Joint Committee of Allied Pottery Manufacturers, and were compiled by Mr. F. SALT (with the exception of a few initialled).

The following particulars respecting patents may be of use to members:—

Country	Address	Cost
Britain ..	Patent Office, London	One Shilling (extra postage outside United Kingdom)
United States	Patent Office, Washington ..	Five cents
France ..	L'Imprimerie Nationale, 87, Rue Vielle du Temple, Paris	One franc
Germany ..	Patent Office, Berlin	
Austria ..	Buchhandlung Lehmann und Wenzel, Wien I, Kärntnerstrasse, 30	
Denmark ..	Patent Office, Copenhagen ..	One krone
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Japan ..	— — Tokyo	Price not stated
Australia ..	Government Printer, Melbourne	One shilling

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In ordering a copy of a patent, the number of the patent and year of the patent, the name of the patentee and the subject of the invention should be stated.

Titles of Journals Abstracted, with Abbreviations.

Allg. Tonind. Ztg... "Allgemeine Tonindustrie Zeitung" (Czecho-Slovakia)
Amer. J. Sci..... "American Journal of Science" (American)
Amer. Min..... "American Mineralogist" (American)
Analyst..... "The Analyst" (British)
Ber. D. K. Ges. .. "Berichte der Deutschen Keramischen Gesellschaft" (German)
Blast Fur..... "Blast Furnace & Steel Plant" (American)
Brennstoff..... "Brennstoff-Chemie" (German)
Brick..... "Brick & Clay Record" (American)
Brick Pot. Tr. J..... "Brick & Pottery Trades Journal" (British)
Brit. Claywr..... "British Clayworker" (British)
Bull. Imp. Inst..... "Bulletin of the Imperial Institute" (British)
Can. Chem. Met..... "Canadian Chemistry & Metallurgy" (British)

Cement Eng. News..... "Cement & Engineering News" (American)
Cer..... "La Céramique" (French)
Cer. Ind..... "Ceramic Industry" (American)
Ceramist..... "The Ceramist" (American)
Cer. Vet..... "La Ceramica ed il Vetro" (Italian)
Chem. Age..... "Chemical Age" (British)
Chem. Appar..... "Chemische Apparatur" (German)
Chem. Met. Eng... "Chemical & Metallurgical Engineering" (American)
Chem. News..... "Chemical News" (British)
Chem. Tr. J. "Chemical Trade Journal & Chemical Engineer" (British)
Chem. Zentr..... "Chemisches Zentralblatt" (German)
Chim. Ind..... "Chimie et Industrie" (French)
China Rev..... "China Clay Trade Review" (British)
Claywr..... "Clayworker" (American)
Corr. Cer..... "Corriere dei Ceramisti" (Italian)
Deut. Töp. Zieg. Ztg. "Deutsche Töpfer und Ziegler-Zeitung" (German)
Diamant..... "Diamant und Glas-Industrie Zeitung" (German)
Econ. Geol..... "Economic Geology" (British)
Faenza..... "Faenza" (Italian)
Feuerung..... "Feuerungstechnik" (German)
Gas J..... "The Gas Journal" (British)
Gas World..... "Gas World" (British)
Gazz. Chim. Ital..... "Gazzetta Chimica Italiana" (Italian)
Giorn. Chim..... "Giornale di Chimica industriale ed applicata(Italian)
Glashütte..... "Glashütte" (German)
Glas-Ind..... "Die Glasindustrie" (German)
Glass Ind..... "The Glass Industry" (American)
Ind. Chim..... "L'Industrie Chimique" (French)
Ind. Man..... Industrial Management" (British)
J. Amer. Cer. Soc. "Journal of the American Ceramic Society" (American)
J. Amer. Chem. Soc. "Journal of the American Chemical Society" (American)
J. Chem. Soc..... "Journal of the Chemical Society" (British)
J. Ind. Eng. Chem. "Journal of Industrial & Engineering Chemistry"(Amer.)
J. Soc. Chem. Ind. "Journal of the Society of Chemical Industry" (British)
J. Soc. Glass Tech. "Journal of the Society of Glass Technology" (British)
Kalk Schm.-Ztg..... "Kalk-, Gips-und Schamotte-Zeitung" (German)
Ker. Rund..... "Keramische Rundschau" (German)
Met. Erz..... "Metall und Erz" (German)
Min. Met..... "Mining and Metallurgy" (American)
Nature..... "Nature" (British)
Pat. J..... "The Illustrated Official Journal (Patents)" (British)
Porz. Glas..... "Die Porzellan und Glashandlung" (German)
Pot. Gaz..... "Pottery Gazette" (British)
Pot. Glass Rec..... "Pottery and Glass Record" (American)
Prod. Chim..... "La Revue des Produits Chimiques" (French)
Quarry.... "The Quarry & Surveyors' & Contractors' Journal (British)
Rev. Mat. Constr. Trav. Pub. "Revue des Matériaux de Construction et de Travaux Publics" .....(French)
Rock Prod..... "Rock Products" (American)
Sprech..... "Sprechsaal" (German)
Stahl Eis..... "Stahl und Eisen" (German)
Südd. Tonind. ..... "Süddeutsche Tonindustrie" (German)
Tonind. Ztg..... "Tonindustrie Zeitung" (German)
Tonwar. Ofen Ztg..... "Tonwaren Ofen-und Töpfer-Zeitung" (German)
TRANS..... "Transactions of the Ceramic Society" (British)
Trans. Faraday Soc..... "Transactions of the Faraday Society" (British)
Verre..... "Le Verre" (Belgian)
Zeits. angew. Chem..... "Zeitschrift für angewandte Chemie" (German)

*** The first number represents the number of the volume, the last the year of publication, and intermediate numbers the page or pages where the subject is discussed.

Abstracts.

I.—RAW MATERIALS.

GENERAL.

AN OUTLINE OF THE USES OF LIME.—M. E. Holmes (*Chem. Met. Eng.*, **26**, 294, 1922).

QUARTZ AND SAND AS RAW MATERIALS FOR THE FINE-CERAMIC INDUSTRY.—M. Pulfrich (*Ker. Rund.*, **30**, 375, 1922; *Tonind. Ztg.*, **46**, 898, 1922). Mainly a review of the German literature on the subject. The question as to whether the German quartz sand deposits offer a complete substitute for the quartz of the Norwegian pegmatite dykes is discussed.

OCHRES FROM JAMAICA.—(*Bull. Imp. Inst.*, **20**, 10, 1922).—Samples of crude ochre were tested at the Imperial Institute and attempts made to prepare improved products from them. The results are tabulated. By suitable treatment refined pigments could be prepared, but the colour and strength are not sufficiently good to ensure profitable marketing in the U.K.

THE GRAPHITE INDUSTRY OF MADAGASCAR.—A. D. Lumb (*Bull. Imp. Inst.*, **20**, 61, 1922). The production in metric tons rose from 8 in 1907 to 35,000 in 1917, but fell away again to 4,500 in 1920. The graphite is almost entirely of the flake variety and occurs in schists and gneisses in the older crystalline rocks. One sketch map and six references to principal literature are given.

CHROMIUM ORE.—(*Bull. Imp. Inst.*, **20**, 112, 1922). Supplementary information to the monographs on Mineral Resources.

RAW MATERIALS: OCCURRENCE, PREPARATION, ETC.

A NEW SOURCE OF SOAPSTONE IN ONTARIO.—H. S. Spence (*Can. Chem. Met.*, **6**, 205, 1922). An extensive deposit of soapstone occurs one mile west of Wabigoon Station, C.P.R. main line. Its properties, etc., have been investigated by the Canadian Department of Mines.

A BIBLOGRAPHICAL NOTE ON THE ELECTRIC AND OSMOTIC PURIFICATION OF CLAYS.—(*Rev. Mat. Constr. Trav. Pub.*, No. 156, 131B., 1922).

PRODUCTION OF ALUMINA FROM CLAY.—(*Chem. Age*, **7**, 646, 1922).—An investigation into the Mignet process (*U.S. Pat.*, 1,376,563), was undertaken by the U.S. Bureau of Mines. M. proposed to prepare alkaline aluminate by fusing clay, lime and scrap iron with a reducing agent in an electric furnace, so as to reduce the silica and produce calcium aluminate and ferrosilicon. The calcium aluminate being lighter, would float on top substantially free from foreign oxides. It could then be tapped off, cooled, crushed, and leached with sodium carbonate solution to form sodium aluminate and calcium carbonate. The report on the investigation, by C. E. Williams and C. E. Simms, indicates that the prospects of the successful application of the process are extremely poor.

SCOTTISH BAUXITIC CLAY.—G. V. Wilson (*China Rev.*, **5**, 87, 1922). The Ayrshire clays are inferior in quality to china clay. The highest grades are not present in large quantities .

THE FINE CERAMIC RAW MATERIALS OF THE U.S.A.—(*Ker. Rund.*, **30**, 266, 1922). The U.S.A. are still largely dependent upon imported materials, particularly English china-clay.

CALCIUM IN CHEMICAL AND ORGANIC FORM.—O. Loew (*Tonind. Ztg.*, **46**, 977, 1922).

FIRE CLAYS OF THE EASTERN COALFIELD OF KENTUCKY.—H. Ries (*J. Amer. Cer. Soc.*, **5**, 397, 1922). The eastern coalfield of Kentucky contains two horizons of workable refractory clays. One of these, bearing flint, semi-flint and plastic clay is definitely proved to be of upper Pottsville age, and rests unconformably on the Mississippian formations. The other, found in Boyd and eastern Carter county, is in the Allegheny series and carries plastic clay of less commercial value. The object of the paper is to bring out certain facts, not hitherto mentioned, and others which show a difference of opinion with previous investigators. The paper closes with a brief account of the development of the fire brick industry in this area.

NEW KAOLIN DEPOSITS IN THE STATE OF WASHINGTON.—(*Claywr.*, **78**, 127, 1922). Four deposits of residual kaolin have recently been discovered. The quality of the clay, according to the ceramist, H. Wilson, of the U.S. Bureau of Mines, is very similar to that of Cornish clays.

Patents.

TITANIUM OXIDE.—G. Carteret, and M. Devaux (*Pat. J.*, 1,758, 1922). No. 184,132, June 27, 1921. Residual acid is eliminated from titanium oxide by treatment with an alkaline-earth chloride solution. The oxide is then washed with milk of lime or baryta to remove the HCl produced, and is finally dried.

TREATING CLAY.—W. Feldenheimer and W. W. Plowman (*Pat. J.*, 1,759, 1922). No. 184,271, May 9, 1921. Clay is deflocculated in an aqueous medium by means of a dilute solution of meta-phosphoric acid or the meta-phosphate of an alkali either alone or in conjunction with an alkali such as sod. carbonate. The proportion of the deflocculator may be varied according to the hardness of the water used. When flocculation is adopted, an aqueous solution of alum or sodium bicarbonate may be used as a flocculator, as described in Spec. 121,191 (Trans. **19**, 3 (A), 1919).

TREATING CLAY.—W. Feldenheimer and W. W. Plowman (*Pat. J.*, 1733, 1922). No. 175,050, Nov. 8, 1920. Clay is deflocculated with the aid of an alkali resinate or its equivalent, such as a solution of a resin acid in one or more alkalis, the preferred reagent being a solution of common resin in caustic alkali, alkali silicate, or alkali carbonate, or in a mixture of the first two. Subsequent precipitation of the clay from the suspension may be effected as described in Specification 121,191.

REFINING CLAY.—Plauson's Ltd. (*Pat. J.*, 1,761, 1922) No. 184,880, May 21, 1921. Residual clays, especially china clay, are converted into pure kaolin by separation of silica and other silicates by intensive mechanical disintegration at a peripheral speed of over 1,000 meters per minute, preferably in the colloid mill (*Spec.* 155,836) with water and with or without a dispersator, the kaolin being selectively colloidalized. Suitable dispersators are water-glass, tanning agents, humus or humic acid, saponin and other soap-like froth-forming substances, or soluble silicates, aluminates, ferrocyanides, sulphocyanides, and borates. In an example, potash water-glass is employed. The resulting dispersion may be concentrated by ultra-filter presses, etc. (*Spec.* 155,834 and 181,023) and the paste dried.

PHYSICAL AND CHEMICAL PROPERTIES, TESTING, ETC.

ON MELTING QUARTZ.—W. Schuen (*Ker. Rund.*, **30**, 457, 1922). A large number of melting tests were carried out on batches of sand (23 kg.) to which were added 20–100 ozs. of the oxides and sulphates of Al, Co, Ba, Sr, Sn, Zn, Fe, Cu, Pb, P, Sb, and Cr, Carborundum, sugar and wood charcoal. Most of the oxides had insufficient time to alloy with the quartz during the short melting period. They became deposited in powder form between the quartz crystals causing disintregation. The sulphates, however, were more capable of forming alloys. They decomposed at the temperature applied and did not have the same derogatory effect on the strength as the

oxides. Iron oxide coloured the quartz brown and rendered it brittle and quite useless. With iron sulphate the product was green and its strength quite satisfactory. Iron filings gave a product covered with black spots, but quite strong. Carborundum, sugar and wood charcoal, even in small quantities, produced a thoroughly blistered and quite useless specimen. The internal appearance of the fused quartz, which resembles mother-of-pearl, is due to innumerable minute bubbles.

NOTE ON THE EFFECT OF URANIUM OXIDE ON THE FUSIBILITY OF ZETTLITZ KAOLIN.—O. Kallauner and J. Houda (*Sprech.*, **55,** 523, 1922). The fusibility was found to decrease progressively on adding U_3O_8 up to 50%, after which further additions produce an increase in this property. With a U_3O_8 -content of 50% or thereabouts an eutectic mixture of kaolin and urano-uranic oxide, with a melting point at or below cone 15, is obtained.

ON THE COMPOSITION, MICRO-STRUCTURE, AND FUSIBILITY OF CLAYS.—L. Bertrand and A. Languine (*Rev. Mat. Constr. Trav. Pub.*, No. 155, 119 B, 1922). A résumé of the original in *Bulletin officiel de la Direction des Recherches scientifiques et industrielles et des Inventions*, No. 27 (See *Cer.* **25**, 97, 1922 ; TRANS. **22,** 94 (A), 1922).

COLLOQUIUM ON FELSPAR AND FELSPAR DEPOSITS.—R. B. Ladoo (*Bull. Amer. Cer. Soc.*, **1,** 78, 1922).

MECHANISM OF PLASTICITY FROM THE COLLOID STANDPOINT.—G. A. Bole (*J. Amer. Cer. Soc.*, **5,** 469, 1922). Plasticity is caused by the enveloping film of colloidal material which surrounds the clay grains, this film being of opposite polarity to the grain proper. The addition of an electrolyte, acting as a deflocculant, causes the outer layer of the film to be attracted to ions of the same polarity as the clay particle, thus reducing the effective diameter and increasing the polarity of the plasticity inducing particles. Particles which were held by surface forces of "particles in contact" are no longer in contact and are actually repelling each other, due to like and increased polarity. A flocculating ion drives the action in the reverse direction, causing an increase in the depth of the colloid film, thereby increasing the surface in actual contact and decreasing the repulsive force of plasticity inducing particles. The flocculating or deflocculating effect of the ions of an electrolyte depends not only upon their polarity and concentration, but also upon their transport number, the speedier ions such as H^+ and OH^- having the greater effect. With regard to measurement of plasticity, the simple method of touch is shown to be inadequate. The necessity of a unit of measurement is pointed out. In the discussion, Purdy disputes the film hypothesis and maintains that all the requirements are met by assuming that the plastic clay particles have sufficient specific surface (surface per unit volume) to allow the maximum development of the natural physical properties of the material (absorption of salts, holding water films). The balance of evidence goes to show that flocculation and deflocculation result from tension differences rather than from changes in the polarity of the clay particles.

THE MONOXIDE AND OXYCARBIDES OF SILICON—"MONOX" AND "FIBROX."—R. Flusin (*Ind. Chim.*, **9,** 391, 1922). The *monoxide* of silicon can be produced by reducing SiO_2 with silicon, carbon, or silicon carbide in an electric furnace. On a large scale a resistance or arc furnace may be used to reduce siliceous sand with silicon, carborundum or coke. The monoxide is evolved as brown fumes which burn in air to produce silica, but which may be condensed in an inert gas to a reddish-brown deposit. It is impossible to avoid partial dissociation of the monoxide ($2\,SiO = SiO_2 + Si$) and the final product is a mixture of SiO, silicon and SiO_2. To this mixture Potter gives the name "monox." In addition to the above, this product also contains SiC and metallic impurities. "Monox" is a yellowish-brown opaque powder, silky to the touch, with an app. sp. gr. of 0·04 and a true sp. gr. of 2·24. It appears to be a sublimate, for it remains solid at 1,700°C. Its

chem. and phys. properties are discussed. In ceramics it should be possible to substitute this substance for silica. The *oxycarbides* of silicon form a class of compounds in which the carbon content may vary between 6 and 21%. Acheson gives the name of "siloxicon" to this class, of the general formula $(SiC)_nO_1$ in which n varies from 1 to 7. The higher the temp. of formation the greater the value of n. Weintraub has recently obtained a curious variety of siloxicon, to which he has given the name "Fibrox." He heated fragments of silicon in a gas muffle furnace to 1,400–1,500°. At this temp. the silicon commences to fuse and the silicon vapours react with the CO_2 or CO in the muffle to form oxycarbides. W. added calcium chloride as a catalyst, the purpose of which appears to be to maintain the silica scum in a sufficiently mobile state to permit the silicon vapours to escape. It was found that the presence of CO_2 was essential to the formation of "Fibrox"; on introducing decomposable carbonates into the muffle the amount of "Fibrox" produced was increased. Fibrox is a soft, fibrous, elastic substance, consisting of an agglomeration of exceedingly fine fibres. It has a blueish-grey colour, and an apparent density varying between 0·0025 and 0·0030. Its true density varies according to its composition: for SiCO it is 1·84, increasing with decreasing carbon content to 2·2. It is an excellent heat insulator. It is not hygroscopic and is stable in air. On moistening with water it can be compressed into a homogeneous mass and formed into crucibles, which are capable of resisting high temperatures and may replace silica crucibles.

THE MONOXIDE AND OXYCARBIDES OF SILICON.—R. Flusin (*Chem. Tr. J.*, **71**, 445, 1922). Translation of above paper.

PRACTICAL METHODS OF TESTING CLAY.—Hirsch (*Tonind. Ztg.*, **46**, 871, 1922). The geological formation and structure of clays are first briefly discussed. This is followed by a short account of the technical methods of testing the various properties.

CLAY FOR ROOFING TILES.—(*Kalk. Schm. Ztg.*, **29**, No. 14, 1922). An account of the necessary properties and method of testing.

THE PLASTICITY OF CLAYS.—F. P. Hall (*J. Amer. Cer. Soc.*, **5**, 246, 1922). The following are discussed: the term "plasticity" and the methods brought forward for measuring this property; the factors which each method measures; the use of the Bingham plastometer as an instrument for determining the relative plasticity of clays; the need for more efficient methods of measuring plasticity.

NOTE ON THE PROBLEM OF THE DECOMPOSITION OF KAOLIN BY ORGANISMS.—W. J. Vernadsky (*Comptes rend.*, **175**, 450, 1922). Experiments were carried out on a colloidal clay, the analysis of which indicated a pure kaolin $H_2Al_2Si_2O_8 \cdot H_2O$, in order to investigate the formation of free hydrates of alumina by the action of diatoms. Diatomic cultures, containing only Nitzschia and a large quantity of bacteria, were found to thrive well on the clay in glass vessels, isolated from moisture by a layer of paraffin and containing a nutritive medium free from silicon. Subsequent chemical analysis showed that this clay, which had been subjected to the action of diatoms, contained free hydrates of alumina, whilst the same clay treated in like manner in parallel experiments, but sterilised to remove the diatoms, contained none.

II.—MANUFACTURING PROCESSES:

GENERAL.

LAMINATION; DISCUSSION OF CAUSE AND CURE.—J. J. F. Brand (*J. Amer. Cer. Soc.*, **5**, 355, 1922). Two types of lamination are distinguished: first, that which arises from the differential flow of clay through the machines,

i.e., *differential lamination* ; and second, that which results from an imperfect union of formed masses of clay, *interfacial lamination*. When water is added to a clay, a portion is absorbed by the grains or particles, whilst another portion occupies the voids between them, thus in effect serving as a filler. This is generally known as pore water. Another portion occupies the minute spaces between the clay grains and the pools of filler water, forming a system of capillary channels of equal area throughout the mass. This may be called capillary water. A further addition of water causes a distension of the capillary channels and with them of the mass. This may be referred to as water of moldability or in drying as shrinkage water. Clays which have been tempered and pugged contain varying quantities of occluded air, some of which becomes divided into blebs small enough to be contained in the water-filled channels without causing their distension or a separation in local areas. The remaining portion, however, occurs in pockets of a larger volume than can be contained in local areas at low pressure. When such a mass is brought under pressure in an auger machine, these larger pockets, together with the clay enclosing them, become flattened into alternate layers of clay and air. If the clay is of the smooth, plastic, free-flowing type, offering a minimum resistance to its passage through the machine, the laminated mass escapes into the column with no substantial change in structure ; if, however, it is returned to the machine several times, the heavier air layers will be gradually broken up into thinner and more numerous layers and finally into blebs. In such a case, reworking avails but little. With coarse, granular clays, which contain more of the water-filled voids, offering lodgment to a greater portion of the air at points where its weakening influence is at a minimum, repeated pugging does not cause the same comparative loss in plasticity. Thus, if the quantity of air present in the beginning is only sufficient to displace the filler-water, intensive working under pressure would effect an actual cure. Auger lamination is due to that air which has been set free by the friction between the auger surfaces and the clay. This air collects at the tips of the vanes and its only avenue of escape lies between and with the clay-streams moving towards the die. The layers of free air, besides acting as walls which prevent the clay from uniting, also act as lubricants which are largely responsible for any differential flow. Differential lamination is caused not so much by the differential flow arising from the forging ahead of the centre portions of the column, as by the differential twisting which obtains between the auger and the die. The swelling of the clay bar as it comes from the die is due to the re-expansion of the enclosed air.

THE MANUFACTURE OF POTTERY.—(*Brick Pot. Tr. J.*, **30,** 207, 1922). A short, general account of the process of manufacturing earthenware.

GRINDING BROKEN SAGGARS.—(*Brick Pot. Tr. J.*, **30,** 208, 1922). The suitability of the various types of grinding machines is discussed.

MANUFACTURE OF HAND-MOULDED SAND-FACED BRICKS AND TILES.—(*Brit. Claywr.*, **31,** 196, 1922). Deals with the raw materials—the clay, weathering, sand for moulding, sand substitutes, and preparation of the clay.

FILTRATION IN INDUSTRY.—R. Moritz (*Chem. Ind.*, **8,** 501, 1922).

BRICKS FROM DOLOMITE.—(*Blast. Fur.*, **10,** 499, 1922). The Bureau of Mines has made standard-sized bricks, from calcined and raw dolomite, using 10% of the flux Fe_2O_3, Al_2O_3, SiO_2. Calcined dolomite was found unsuitable, as the mud slaked rapidly and all samples cracked badly during drying and burning. Raw dolomite with 10% flux, gave promising results.

THE BAKING OF DRY-PRESSED BRICKS.—(*Brick Pot. Tr. J.*, **30,** 263, 1922). An account is given of some practical experience with a Czerny dry press. The information was communicated to the Austrian Pottery Union at Vienna.

COKE BRICKS.—(*Deut. Töp. Zieg. Ztg.*, **53,** 219, 1922). Coke Bricks were first introduced into the metallurgical industry about 30 years ago.

They were first made of ground coke, bonded with clay. Tar was then substituted for clay as a binder. The hard pieces are picked out of coke containing not more than 8% of ash, and are crushed to a grain size of about 2 mm. and mixed with 20% of warm tar. The mixture is then thoroughly worked up and passed through a pug-mill. The bricks are formed in wooden moulds in the usual way, and dried in a moderately warm room, free from draughts, for 2–3 week. They are best fired in a gas chamber oven to cone 12, and allowed to cool slowly. Well-burned bricks should be light grey in colour and should have a good "ring."

Coke bricks have been used chiefly for lining the bases and boshes of blast furnaces. When employed for this purpose, it is essential that the mortar joints should be as narrow as possible. The mortar consists of finely ground coke, with about 20% of clay, mixed with water. The finished lining must be dried thoroughly, but slowly, before the furnace is put into operation.

THE MAKING OF "OLD" BRICKS.—(*Brit. Claywr.*, **31**, 99, 1922). A description of the method of manufacturing dark red bricks made to appear old, with a rough sandy surface.

MODERN TILE MAKING, II.—A. B. Searle (*Brit. Claywr.*, **31**, 107, 1922). In this second contribution an account is given of the geological distribution of tile clays in Great Britain.

THE MAKING AND BURNING OF GLAZED WARE, II.—(*Brit. Claywr.*, **31**, 112, 1922). An account is given of the properties, composition, etc., of the various British fireclays.

MAKING SAND-LIME BRICKS.—C. A. Breskin (*Rock Prod.*, **25**, No. 19, 24, 1922). A well-illustrated description of the methods employed at the Belt-Line Brick Co's Works, of Minneapolis, where 75,000 bricks are produced daily with the aid of modern machinery.

THE MANUFACTURE OF FLOWERPOTS.—(*Brick*, **61**, 398, 1922). A translation from the German by A. Tauber. Both old and modern methods are described. The requisite properties and method of preparing clays, and the machinery and equipment required, are discussed. (Illustrated).

COMPOUNDING AND PREPARATION OF BODIES, ETC.

REFRACTORY BRICKS FOR LIME KILNS.—(*Deut. Töp. Zieg. Ztg.*, **53**, 290, 1922). The average maximum temp. in lime shaft kilns is approximately 1,350°C., but there is no doubt that this temp. is exceeded to a considerable extent in isolated portions of the combustion zone. In practice it has, therefore, been found that bricks used for lining this part of the kiln must be capable of withstanding a temp. of cone 34 (1,750°C.). To resist abrasion from the mixture of limestone and coke as it falls through the kiln, the bricks should be as dense as possible, the grog used should have a grain-size not exceeding 3 mm., 2 parts of grog to 1 of clay giving a good body. As little water as possible should be used in forming the bricks. Dense bricks also offer greater resistance to destructive chemical agents, such as the slags of impure cokes. Both bricks and mortar should be of the basic type. Bricks with a high silica content are not recommended, since the basic lime readily reacts with the silica. The amount of mortar used between the bricks should be reduced to a minimum ; it should not exceed 10% of the quantity of bricks employed. For the preheating zone, bricks with a refractoriness corresponding to Cone 32 should suffice, while for the cooling zone, Cone 30 bricks may be used. The lining should not be too thin ; it may vary between $9\frac{3}{4}$ and 12", according to the size of the kiln. Suitable dimensions for the bricks are : 8" (200 mm.) wide by 5"-6" (130–150 mm.) thick.

PATENTS.

CRUCIBLES.—M. de Roiboul (*Pat. J.*, 1,746, 1922). No. 179,928, May 5, 1922. Crucibles for fusing refractory materials are composed of 60–80%

zirconium oxide, 13–17% yttrium oxide, up to 10% thorium oxide, and 5–20% erbium oxide. Thorium oxide may be omitted. Cerium oxide may be added up to 20%, and cerium oxide or beryllium oxide may be substituted for erbium oxide.

BERYL IN INSULATOR PORCELAIN.—Brit. Thomson-Houston Co. (*Pat. J.*, 1,758, 1922). No. 184,090, Sept. 27, 1921. From 5 to 35% of beryl is added to the usual porcelain ingredients, *i.e.*, clay, silica and felspar.

PLASTIC COMPOSITION.—G. C. Devonshire and E. T. Foord (*Pat. J.*, 1,760, 1922). No. 184,563, May 12, 1921. A composition for making buttons, insulators, etc., consists of 12 parts ground bone, 3 parts casein, and 2 parts lime, with or without 1–2 parts sodium silicate, sufficient water being added to produce a plastic mass.

METALLIC BODIES.—E. C. R. Marks (*Pat. J.*, 1,762, 1922). No. 185,435, March 8, 1921. Ceramic bodies, refractory or otherwise, with clay as a base, are mixed before moulding with a metal or alloy in a finely-divided state, to enable them to be dried quickly before burning. Aluminium or magnesium, or alloys thereof, or zinc may be used. For refractory crucibles, etc., sand, graphite, silicon carbide, lime, magnesia, bauxite or zirconia may be added to the clay. A glazed product may be obtained by incorporating with the mixture a further non-ferrous metal such as copper, nickel, monel metal, chromium or cobalt in a finely-divided state.

BRICKS CONTAINING PEAT.—L. le W. Hamon (*Pat. J.*, 1,766, 1922). No. 186,355, Sept. 13, 1921. Four compositions, containing peat, for the manufacture of bricks, blocks, etc., are described.

REFRACTORY COMPOSITION.—E. D. Frohman (*Pat. J.*, 1,768, 1922). No. 186,968, June 10, 1921. The mixture contains finely-divided fireclay, a siliceous refractory material such as ganister or asbestos, and a vegetable substance which acquires binding properties when moistened with water, such as sulphite pitch (a bye-product of the manufacture of sulphite pulp), dextrine, or gum arabic. The composition is mixed with water when required for use.

SHAPING, MOULDING, DRYING, ETC.

THE MAIN PRINCIPLES OF DRYING.—F. Klages (*Deut. Töp. Zieg. Zeit.*, **53**, 112, 1922). In open-air drying the chief agents are wind and sun. In artificial drying similar conditions should be aimed at as far as possible, *i.e.*, the whole of the ware should be uniformly exposed to the heat and change of air (artificial draught).

PRESSING ROOFING TILES.—(*Kalk. Schm. Ztg.*, **29**, No. 7, 1922). A short general discussion.

THE DRYING SYSTEM.—(*Brit. Claywr.*, **31**, 110, 1922). Modern methods of drying bricks and tiles on a large scale are discussed.

DRYING BRICKS.—K. Dümmler (*Deut. Töp. Zieg. Ztg.*, **53**, 349, 1922). The temperature of the drying rooms should never be allowed to reach 100°C.; a more suitable temp. is *ca.* 50°C. D. recommends the placing of a "mixing chamber" before each dryer; in this chamber the hot air from kilns, etc. can be cooled with outside air to the required temp. before entering the dryer. The arrangement should always be such that a large number of bricks can be dried with little heat and much air, and not a few bricks with much heat and little air.

Patents.

SPECIAL SHAPES FOR BRICKS OR BLOCKS.—J. A. Malcolm (*Pat. J.*, 1,757, 1922). No. 183,509, Feb. 25, 1921. A description is given of building blocks comprising two sections with interlocking bulbous projections and a damp-proof layer between the projections.

DRYING CHINA CLAY.—T. Rigby (*Pat. J.*, 1,757, 1922). No. 183,535, Apr.16, 1921. Describes a method of drying pastes of china clay in films, when taken from the settling pits. Specifications 149,055, 150,963 and 187,035 are referred to.

METHOD OF MAKING ELECTRIC INSULATORS.—J. F. Scheid and Schomberg and Söhne (*Pat. J.*, 1,760, 1922). No. 184,725, Oct. 10, 1921. See TRANS., **20**, 60 (A), 1921.

SPOUTS FOR TEA-POTS, ETC.—R. H. Dodd (*Pat. J.*, 1,761, 1922). No. 184,819, Oct. 10, 1921. A tea-pot, coffee-pot, etc., is provided with a threaded socket surrounding a strainer and engaging a symmetrical spout. A rubber washer is held in the joint.

TEA-POT SPOUTS.—F. Tunnicliffe (*Pat. J.*, 1,761, 1922). No. 185,042, Oct. 26, 1921. To prevent drips from the spout, a sharp cut-off of the flow of the liquid is formed by the junction of the inner face of the breast of the spout and the inclined back face of the lip; a shallow recess to retain the drips is provided inside the lip.

KILNS, OVENS, MUFFLES; FIRING TECHNIQUE, ETC.

BURNING A DOWN-DRAUGHT KILN.—E. Lovejoy (*Claywr.*, **78**, 346, 1922). The operation takes place in four distinct stages—water-smoking, oxidation, heating up, and heat soaking. The paper is written from the practical standpoint.

BURNING FACE BRICKS WITH OIL.—H. T. Horwell (*Brick*, **61**, 712, 1922). A general manager describes how firing with oil reduced the burning time by 3 days and improved the quality of the ware.

FIRING BOILERS AND FURNACES WITH POWDERED COAL.—P. Frion (*Chem. Ind.*, **8**, 736, 1922). A lengthy account of the various methods applied industrially. The different types of furnaces are illustrated.

FUEL PURCHASE.—C. F. Wade (*Eng. Ind. Man.*, **8**, 307, 1922). The average purchaser has little knowledge of the composition and heat-value of the fuel he buys. The following factors connected with the commercial value of a fuel, are discussed: calorific value; percentage ash and its composition; percentage moisture; percentage hydrogen (volatile); size and physical characteristics; cost per ton in bunkers.

DEVELOPMENTS IN 1921 IN ELECTRIC VITREOUS ENAMELLING FURNACES.—J. W. Carpenter (*J. Amer. Cer. Soc.*, **5**, 409, 1922). After a description of a number of electric furnaces in operation on various plants, the writer gives some interesting operating data. One furnace is arranged to deliver at least 25 heats of 110·4 lb. per hour as follows: supporting racks 60 lb.; steel ware 32 lb.; enamel 18·4 lb.; Gross production per hour 2,760 lb.; net production per hour 1,260 lb. The net efficiency is approximately 6½ lb. of material burned per kw. hr. of power consumed. The furnace operates at present at 1,750°F., the maturing temp. of the enamel being 1,550°F. It is predicted for this furnace that the quantity of tin oxide used in the enamel can be decreased materially because of the very positive temp. at which the furnace regularly operates. In one factory two electric furnaces have replaced three coal furnaces. The cost of the coal itself, plus the labour for unloading and firing, etc., was equal to the cost of power for the electric furnaces. For the latter, however, the labour costs were lower, the net saving being approximately 20 dollars per day. An entirely new principle in firing was put into operation during the past year, the fundamental idea being: moving furnace, stationary ware. The installation is briefly described as follows: There is a stationary platform, 54 in. wide and 60 ft. in diameter, upon which the ware is placed by hand. The furnace proper revolves over the platform, moving along a standard railway gauge track. The furnace chamber is 21 ft. in length in the main section, to each end of which a hood, 8 ft. long, is attached. Doors are provided at each end of the main section

as well as at the end of the hoods. The latter are intended to prevent excessive heat losses, as the doors are constantly open just high enough to clear the ware. A variable speed motor (capacity 4½ to 9 ft. per min.) drives the furnace round the platform at an average speed of 7 ft. per min., so that the ware is covered by the main heating chamber for a period of 3 minutes. The furnace is to be operated most of the time with 500 kw. The maximum capacity is 3,000 lb. of enamel ware per hour, and ordinary unskilled labour can be used to load and unload the table. Any desired temperature up to 1,850° can be attained.

A SMALL CONTINUOUS TUNNEL KILN FOR FIRING SPARK PLUG PORCELAIN INSULATORS.—S. J. McDowell and P. D. Helser (*J. Amer. Cer. Soc.*, **5**, 267, 1922). The design of the kiln is based on the idea of firing a small, thin mass of ware at a rapid rate. Only 12 hours are required to complete the burning operation. The kiln has a total length of 75 ft. and an interior width of 2 ft. 8 in. The ware is passed through in a single, unprotected, horizontal tier and is subjected to direct fire. The kiln is operated at Cone 18 half down, city gas (of approx. 550 B.T.U. per cu. ft.) being used, with a burner equipment which gives a modified form of surface combustion. The initial cost is low. The kiln is of simple construction, permitting rapid heating and cooling. The output, therefore, depends upon the individual pieces of ware being able to safely absorb the heat necessary for their vitrification and to withstand the rapid heating and cooling treatment.

AN AUTOMATIC DRAUGHT REGULATOR FOR CERAMIC KILNS.—(*Rev. Mat. Constr. Trav. Pub.*, No. 154, 104 B, 1922; *Pat. J.*, 1,763, 1922. No. 185,667). An automatic draught regulator, which has been in successful operation for two years on a French brick and tile works, consists of an inverted cylinder 1·6 metres in diameter partially submerged in an annular tank filled with water (after the manner of a gas tank) the whole being built directly over the main damper in the chimney flue. The water in the annular tank renders the apparatus air tight. The inverted tank is counterpoised by means of a weighted chain passing over pulleys on a metallic framework, which is built into the masonry. The damper is also connected to the base of the inverted cylinder. When the regulator is in operation, three forces are acting on the cylinder: (1) atmospheric pressure which is exerted on the outer, or upper surface, and which may be considered as constant; (2) the draught caused by the chimney, which acts on the lower, or internal surface of the cylinder base; this force tends to lower the cylinder, and with it, the damper; (3) detachable weights, which are added to the counterpoise in order to pull against the draught pressure. The detachable weights are so chosen as to correspond to 1 millimetre of draught pressure. If x represents the second force (natural draught), and y the third (total of detachable weights), it will be seen that the damper is stationary if $x=y$. When x is greater than y the damper descends and the draught is gradually decreased until x again equals y. If, on the other hand, y increases, the draught will increase owing to the raising of the damper until equilibrium is again restored.

THE HARROP TUNNEL KILN.—W. E. Cramer (*J. Amer. Cer. Soc.*, **5**, 492, 1922). The kiln described is located at the plant of the General Porcelain Co., Parkersburg, Va. It is of the direct-fire type and is firing low tension insulators, special porcelain and a general line of standard electrical porcelain. It is equipped for burning either fuel oil or natural gas, or both together. With a few minor changes in the furnaces, coal could also readily be used. The kiln is 321 ft. in length, with an inside width of 54½ inches. The total height is about 11 ft. Of the total length, 160 ft. are taken up in the heating up zone, 42 ft. in the firing zone and 119 ft. in the cooling portion. There are eight furnaces in the firing zone, four on each side. The kiln cars are 6 ft. long and 58½ in. wide, the effective setting space being 50½ in. by 5 ft. 9 in. Sand seals protect the metal parts of the cars throughout the entire length of the kiln. An automatic hydraulic ram propels the cars. The total power required is 21 motor horse power, but under normal operation only

about 80% of this is used. The kiln is operated by four firemen, two men in two 12 hour shifts. These men attend to the charging of the cars, removing them from the kiln, and also the regulation of the heat, which requires attention when three different firing temperatures are used. For instance, in firing three different kinds of ware, the kiln must operate at either Cone 10, 11 or 12 and be quickly changed from one temperature to another. This change can easily be made by regulating the burners and the car schedule in from one to two hours. The entering temp. of the kiln varies between 100°F. and 220°F. The heating curve rises uniformly to the temperature of Cone 10, 11 or 12. It then falls off quickly, and finally more slowly as it nears the kiln exit. The temp. at the discharge end varies between 175°F. and 350°F. The cooling air is first drawn under the cars from the atmosphere by means of a suction fan. From under the cars, it is drawn through the fan and tempered with atmospheric air and then divided in three ways. Part of it is forced into the discharge end and serves to cool the ware. The second portion is forced through a flue over the entire discharge end, whence it is led down over the furnace arches and delivered into the furnaces as secondary air of combustion. The combustion gases leave the furnaces and enter directly into the tunnel proper, travelling horizontally toward the charging end. Near the entrance they are drawn into flues in the side walls by the draught fan. The temp. of these gases when they enter the chimney is 350°F. The cross-sectional heat distribution is said to be excellent. An exclusive feature of the Harrop kiln is the construction of the inner walls of the kiln, which allows an easier passage of gasses through the bottom of the setting, so that it is found possible to maintain continuously a higher temp. along the bottoms of the setting than along the tops. The centre bung of saggars is as well fired as the two outer ones. The kiln was designed to have a maximum capacity equivalent to that of 12 sixteen-foot diameter periodic kilns per week, using round saggars. With square saggars, the quantity of ware placed on a car can be increased by 55% thus giving greater kiln efficiency. Approximately 35% in firing time is saved over periodic kilns; at a one-hour schedule a car will remain in the kiln 52 hours. Fuel consumption tests were also conducted, which also showed a considerable saving over periodic kilns. Other advantages of the kiln are: the production of a uniformly-fired product, and a lower labour cost, all the placing and drawing being centralized. The installation costs of the kiln are considerably less than the cost of the number of periodic kilns necessary to give the same output.

THE MINTER SYSTEM OF BURNING AND DRYING.—(*Brick*, **61**, 102, 1922). The Minter System is essentially the application of a continuous principle of burning to a number of periodic kilns. All that is required is the addition of a specific flue system and fans to the existing circular down-draught kilns. The flues appear to be of large dimensions and are constructed below the surface. The mere manipulation of dampers is all that is necessary in regulating the system. The cycle operates in the following manner: Kiln No. 1 has just finished burning and is cooling; No. 2 is on hot fire; No. 3 is being preheated entirely by waste gases from No. 2; No. 4 is water-smoking with the waste heat from No. 1; No. 5 is being set with green ware; No. 6 is drawing, and No. 7 is either cooling or drawing. Kiln No. 2 is being fired to maturity in the usual manner with live fuel. Forced draught may be applied if conditions require it, in which event part of the draught is supplied by the atmosphere and part from the cooling kiln No. 1. To accomplish this, a portable fan is placed over the damper, the hot air is drawn from Kiln No. 1 through the direct connecting flue with Kiln No. 2, forced through a flue circling the kiln and then into the furnaces of kiln No. 2. Kiln No. 3 is receiving all the waste heat from No. 2 and, in addition, a portion of the waste heat from the cooling kiln No. 1. This kiln attains a low red heat before any fuel is burned in the fire boxes. The ware set in Kiln No. 4 is water-smoked to a bone-dry state entirely without the use of special fuel. No hot combustion gases from No. 2 are used for this purpose. Any desired temperature may be obtained and there is no smoke or sulphur in the dryer.

The continuous principle may be applied to five, seven, nine or more down-draught kilns and where the number is large two fires may be used.

A NEW TYPE OF GAS-FIRED VITREOUS ENAMELLING FURNACE.—H. H. Clark (*J. Amer. Cer. Soc.*, **5**, 478, 1922). The furnace has a working chamber 4 ft. wide, by 3 ft. high by 10 ft. long and is heated by 10 gas burners, five on each side. It can be brought to working temp. in less than an hour and will turn out 12 to 24 loads an hour. The average gas consumption is about 1,800 cu. ft. of 500 B.T.U. gas per hour when firing 600 sq. ft. of flat ware, totalling 600 lb., representing 240 pieces, at an average temp. of 1,700°F. The ware produced has a very high gloss. The first cost is low and no foundations other than a cement floor, are required. Maintenance costs are very low, as there is no muffle or combustion chamber.

BURNING FACE BRICKS WITH OIL.—E. A. Morse (*Brick*, **61**, 634, 1922). The method adopted on an Indiana plant for burning with oil is described. On changing from coal to oil a saving of 1·51 dollars per 1,000 bricks was attained.

THE KIRKE PATENT WASTE-HEAT BOILER.—(*Brick Pot. Tr. J.*, **30**, 264, 1922).

THE DETERMINATION OF THE MOISTURE CONTENT OF GENERATOR GAS.—E. Maase (*Feuerung*, **11**, 27, 1922). A description of apparatus and of the method of calculation is given.

REFRACTORY CEMENTS AND PROTECTIVE COATINGS.—C. E. Bates (*Claywr.*, **78**, 146, 1922). Many firebrick failures are directly due to the improper use of fireclay mortar. Some bricklayers insist on adding various substances to the ground fireclay used in laying firebricks, but it is a dangerous practice. The following are substances most commonly added and their effect: (1) Common salt—decreases the refractoriness of fireclay; (2) sand; (3) cement; (4) water-glass; (5) lime; (6) asbestos; all these decrease the refractoriness. (7) Fireclay grog increases the refractoriness. Many of the patented refractory cements and protective coatings are really harmful, as they contain compounds which act as fluxes at high temperatures. The most satisfactory material to use for laying bricks is a thin batter made of high grade fireclay to which is added 50% of finely ground firebrick bats. Carborundum dust, mixed to pastry consistency with water, makes a very good protective coating, but it does not greatly increase the life of the bricks.

THE "POCKET" GAS TESTOR.—H. Strache and K. Kling (*Feuerung*, **11**, 13, 1922). A description (with sketch) of a small, portable apparatus for testing rapidly the CO_2-content of gases. No liquids, except petroleum in the manometer, are used; soda-lime acts as the absorbing medium.

USE OF FORCED DRAUGHT FOR TERRA COTTA KILNS.—J. L. Carruthers (*J. Amer. Cer. Soc.*, **5**, 449, 1922). A description is given of a system which has been successfully applied to periodic muffle kilns. Special features of the system include: (1) special type of grate used; (2) overhead air flues, and (3) use of cheap bituminous slack coal. Compared with the natural draught system formerly used, the advantages are: (1) a net saving of about 20% in burning costs; (2) better control of kiln atmospheres and temperatures; (3) less skilled labour required.

STABILITY AND DESIGN OF A KILN STACK.—T. W. Garve (*J. Amer. Cer. Soc.*, **5**, 455, 1922). The various cross-sections and the difference in stability of round, octagonal and square stacks are discussed. Calculations on dead weight and wind pressure are illustrated with reference to an average kiln stack. A number of important practical hints on design and construction are given (9 Figs.)

FIRING OF CERAMICS IN ELECTRIC FURNACES.—E. L. Smalley (*Glass Ind.*, **3**, 205, 1922). The advantages of electrical furnaces include: the perfect control of temperature, cleanliness of the atmosphere, and even

distribution and uniformity of temperatures. The application of electric heat to glass manufacture is discussed. In the manufacture of bi-focal lenses, the percentage of rejects and losses was reduced from 18–20% in gas furnaces to 2–3% in the electric furnace.

PROBLEMS OF HEAT ECONOMY IN GERMANY.—W. Quack (*Zeits. angew. Chem.*, **35**, 621, 1922).

BEST POSSIBLE RESULTS FROM HOFFMANN KILNS.—(*Brit. Claywr.*, **31**, 208, 1922). A discussion, by four correspondents to the journal, of the best methods of working Hoffmann kilns.

IS HOT AIR ESSENTIAL FOR KILNS?—(*Brit. Claywr.*, **31**, 211, 1922). By the use of hot air, a saving of 10% of fuel is possible with comparatively crude arrangements. By the full application of hot air, a saving of 40% can be effected in intermittent kilns working at temperatures of 1,300-1,400°C. The best means of heating the air is by means of a regenerator, or a recuperator.

CALCULATING HEAT LOSSES IN FURNACES.—O. I. Hansen (*Blast Fur.*, **10**, 437, 1922). A new method is described for determining heat losses due to incomplete combustion. A modification of the ordinary Orsat apparatus is used in the determinations. The flue gas is first examined for CO_2 and then passed through a heated platinum tube, after which, any combustion taking place in the tube is indicated by a contraction in volume. The method of calculating results is explained.

THE "KIRKE" PATENT WASTE HEAT BOILER.—(*Brick Pot. Tr. J.*, **30**, 214, 1922). A short description, with two illustrations.

THE LIMITATIONS OF THE CONTINUOUS KILN.—(*Brit. Claywr.*, **31**, 174, 1922). A reply to an enquiry as to the means of obtaining the best possible results from Hoffmann kilns.

THE USE OF THE PYROMETER.—(*Brit. Claywr.*, **31**, 187, 1922). A description of an installation, which has been in continuous use since 1917, on 2 kilns of 16 chambers each. The recorder is housed in a lock-up room between the two kilns, and the instrument itself is accessible only to the work's foreman. The advantages of pyrometric control of firing are pointed out.

AN ELECTRIC FURNACE FOR MELTING QUARTZ.—W. Schuen (*Tonind. Ztg.*, **46**, 1,121, 1922). A description (with sketches) is given of a furnace in which hollow quartz blocks are melted. A hollow carbon rod is used as resistor.

A NEW GAS-FIRED CHAMBER KILN.—(*Pot. Gaz.*, **47**, 1,535, 1922). A description of the "Potter" kiln at the works of the Domestic Porcelain Co., Fenton (1 photograph). The kiln consists of 16 chambers in a double row of 8, with a passage between, and is gas-fired from a Duff producer.

THE JOHN WRIGHT TUNNEL OVEN.—(*Pot. Gaz.*, **47**, 1,538, 1922). An account of the tunnel oven at the British Pottery Co's works at Tunstall (3 illustrations). The tunnel is over 200 ft. long, 6 ft. high and has an internal width of 5 ft. A temp. of 1,200°C. is reached in the firing zone. Gas is supplied from a Horsehay producer.

ARE TUNNEL KILNS PRACTICABLE FOR BRICKS?—(*Brit. Claywr.*, **31**, 152, 1922). The lack of success in using tunnel kilns for firing bricks is due entirely to faulty design or to mismanagement. The most common mistake is made in building the kiln too short. Other important points are: a correctly designed arch; strict punctuality in working; suitable types of gas producer; properly designed cars; method of propelling cars; full attention to details of design and operation.

DOWNDRAUGHT KILN CONSTRUCTION.—E. A. Burrows (*Brit. Claywr.*, **31**, 159, 1922). Some practical suggestions from a man engaged in constructing continuous downdraught kilns, with a patented automatic damper control, and advance drying system. Several sketches and a Standard Construction Table are included.

THE GASIFICATION OF EARTHY LIGNITE WITH A HIGH WATER-CONTENT.—G. H. Meyer (*Sprech.*, **55**, 423, 1922). An illustrated account of the modern process.

DETERMINATION OF THE HYDROCARBONS IN TECHNICAL GASES.—G. Wollers (*Stahl Eis.*, **42**, 1,449, 1922). The determination by absorption of acetylene from the hydrocarbons of the ethylene series, and the separation and determination by condensation of the saturated and unsaturated hydrocarbons are discussed.

THE CO_2 CONTENT OF FLUE GASES, AND FURNACE EFFICIENCY.—J. Hudler (*Feuerung*, **11**, 1, 1922). The following two problems are discussed from a theoretical standpoint: (1) if the temp. of the flue gases of a steam boiler remains constant at 300° and the CO_2 content varies between 9 and 18%, what are the stack losses and what is the capacity per hour ?; (2) what are the stack losses if the CO_2 content varies between 9 and 18% and the steam generating capacity per hour is maintained constant?

KNACKS IN SETTING UP-DRAUGHT KILNS.—E. Petts (*Brick*, **61**, 240, 1922). Six sketches are given to illustrate the method of setting.

FUEL SUBSTITUTES FOR BRICKWORKS.—(*Rev. Mat. Constr. Trav. Pub.*, No. 155, 113 B, 1922). Some notes on the use of lignite.

PATENTS.

TUNNEL KILNS.—C. F. Bailey (*Pat. J.*, 1,757, 1922). No. 183,708, July 23, 1921. Relates to a tunnel kiln of the kind in which the inlet and outlet are at lower levels than the middle heating zone. The trucks containing the ware are carried along tracks by an endless chain, provided at intervals with pairs of hinged arms, the outer ends of which are adapted to engage in pockets underneath the trucks.

GAS-FIRED SHAFT KILN.—C. F. Priest (*Pat. J.*, 1,758, 1922). No. 184,057, Aug. 3, 1921. The gas is supplied from a main to a belt round the burning zone of a shaft-kiln for burning limestone. It passes thence through value-controlled openings to hopper-shaped dust and tar collecting chambers and the gas ports. The air for combustion is supplied through dampered openings in the discharge hopper.

UTILIZING WASTE HEAT.—C. F. Twigg (*Pat. J.*, 1,760, 1922). No. 184,540, Apr. 14, 1921. The hot air from any chamber passes through a branch pipe connecting to, or projecting through an aperture in the kiln chamber, and thence by a central main pipe and a flue to a distributing fan.

FURNACE LININGS.—Ferolite Ltd. and H. B. Clapp (*Pat. J.*, 1,756, 1922). No. 183,219, Apr. 15, 1921. A method of lining gas-producers, electric furnaces, crucible furnaces, and the like is described. The lining is made from a mixture of chromite and ferro-silica ground to a suitable fineness and mixed with a binding material such as sodium or potassium silicate. The plastiic mass may be made into bricks or slabs, or may be tamped in a continuous layer round a core.

POTTERY KILN.—C. F. Bailey (*Pat. J.*, 1,760, 1922). No. 184,716, Sept. 20, 1921. Three kilns are built integral side by side at approximately the same level, fire places being provided in the outer walls of the outer kilns in communication with flues round the walls and under the floor of the two outer kilns. These flues terminate in a flue under the floor of the central kiln. The gases pass under the floor of this kiln to a flue round its walls and thence to a cone inside the main chimney. By means of a damper, this inner cone may be closed to "store heat" while the kilns are cooling. The interiors of the kilns are in communication with the chimney. To expedite cooling, the fire bars are carried on an inclined plane and may be withdrawn, thus discharging the fire into ash-pits containing water.

REGENERATOR BLOCKS.—H. Schulz (*Pat. J.*, 1,760, 1922). No. 184,744, Dec. 29, 1921. Each block has an external annular channel and gaps in the head and foot portions, whereby the channels are connected to form a network of straight longitudinal and transverse passages.

THE CONTROL OF GLAZE-FIT BY MEANS OF TENSILE TEST SPECIMENS.—F. H. Riddle and J. S. Laird (*J. Amer. Cer. Soc.*, **5**, 500, 1922). In selecting a suitable glaze for a particular body by the inspection of a tri-variant system, it is usually found that the glazes within a more or less wide field all appear equally satisfactory, and the selection of the best glaze within this area is often a matter of judgment only. The glaze nearest the centre of the area is not necessarily the most suitable. A glaze which appears satisfactory when newly fired will sometimes develop crazing on standing; this is often the case with bright-glazed wall tiles. A new method of comparing glazes as regards fit is described. Test specimens from 0·4 to 0·5 inch in diameter are turned to the requisite form, and after glazing all over and firing, are broken on an ordinary cement testing machine. The effect of the glaze may be to (*a*) materially increase, (*b*) have little effect upon, or (*c*) markedly decrease the breaking strength of the specimen, these effects apparently depending upon the extent to which the glaze "fits" the body. The following table shows the results with a one-fire cone 13 porcelain with various glazes:

Glaze No.	Tensile Strength (lbs. per sq. in.)	Remarks on glaze
22	7520	Good bright glaze
16	6954	do.
691D	6590	Somewhat pinholed
665	5710	Immature, matt
666	2052	Crazed, immature

The writers conclude that there can be no question as to the intimate relationship between the glaze "fit" and the strength of small, glazed, porcelain objects, and although no actual experiments have been conducted, there appears to be no reason why the same should not also apply to semi-porcelain or unvitrified bodies. Failure of the glaze to "fit", especially if crazing actually develops, produces strains in the surface of the body so that a much smaller external load is required to cause breaking of the specimen.

A MODIFICATION OF THE EMPIRICAL FORMULA IN GLAZE AND ENAMEL CALCULATIONS.—J. E. Hansen (*J. Amer. Cer. Soc.*, **5**, 338, 1922). The disadvantage of the type of molecular formulae as usually employed, lies in the fact that they merely express that certain elements are present in certain proportions, the mineralogical and physical condition in which these elements are introduced being entirely neglected. But these neglected factors may, in many cases, be more important than the formal ultimate analysis. The writer shows how, by calculation back to the batch mixture, the old type of molecular formula may be misinterpreted. An enamel formula of the following kind:

$$\left.\begin{array}{l} 0{\cdot}357\ Na_2O \\ {\cdot}083\ K_2O \\ {\cdot}172\ CaO \\ {\cdot}080\ BaO \\ {\cdot}242\ ZnO \\ {\cdot}066\ PbO \end{array}\right\} : 0{\cdot}120\ Al_2O_3 : \left\{\begin{array}{l} 1{\cdot}016\ SiO_2 \\ {\cdot}244\ B_2O_3 \\ {\cdot}044\ Sb_2O_3 \\ {\cdot}323\ F_2 \end{array}\right.$$

could be more satisfactorily expressed, according to the author, as follows:

$$\left.\begin{array}{l} 0{\cdot}274\ Na_2O \\ {\cdot}083\ Na_2F_2 \\ {\cdot}083\ K_2O \\ {\cdot}059\ CaO \\ {\cdot}113\ CaF_2 \\ {\cdot}080\ BaO \\ {\cdot}242\ ZnO \\ {\cdot}066\ PbO \end{array}\right\} : 0{\cdot}106\ Al_2O_3 : {\cdot}014\ Al_2F_6 : \left\{\begin{array}{l} 0{\cdot}974\ SiO_2 \\ {\cdot}042\ SiF_4 \\ {\cdot}244\ B_2O_3 \\ {\cdot}044\ Sb_2O_3 \end{array}\right.$$

The advantages of this new type of formula are that (1) it presents its data in the usual simple and graphic manner ; (2) it indicates the mineralogical and physical condition in which most of the important constituents are introduced into the batch ; (3) it admits of but little danger of obtaining the wrong batch mixture upon calculation back to the raw materials ; and (4) the conclusions to be drawn from it are quite fixed and definite.

A STUDY OF FAIENCES.—AGREEMENT BETWEEN BODY AND GLAZE.—A. Cornille (*Rev. Mat. Constr. Trav. Pub.*, No. 155, 121 B, 1922). The work of Th. Deck is mentioned. With regard to the use of boric acide, it is maintained that a non-crazing and non-peeling body and glaze combination should be aimed at before adding boric acid. The latter may then be substituted for silica in the glaze, a better agreement being thus obtained. A practical method of testing the agreement between the coefficients of expansion is suggested. Instead of employing plaques, small, shallow pans, made with the body, are filled with the glaze. After firing, a layer of glaze about 5 or 6 mm. thick is formed in the pans. If the combination is satisfactory, there will be no crazing of the glaze and no rupture of the pans (peeling).

THE FIELD OF PORCELAIN GLAZES MATURING BETWEEN CONES 17 AND 20.—R. Twells, Jr. (*J. Amer. Cer. Soc.*, **5**, 430, 1922). A typical porcelain glaze formula $\left.\begin{matrix}0{\cdot}3\ K_2O\\0{\cdot}7\ CaO\end{matrix}\right\} x\ Al_2O_3\ y\ SiO_2$ was used. The RO was held constant, the Al_2O_3 was varied between 0·8 and 1·6, and the SiO_2 between 6 and 16 equivalents. The glazes were applied to green porcelain discs and fired to cones $17\frac{3}{4}$, 18, 19 and 20 in commercial kilns. The glazes are plotted according to batch weights and empirical formula. The location of the best glazes at each temp. is shown on triangular diagrams. Under the conditions described, the best glazes for these temperatures have the following range of composition : Clay 21·9—27·2% ; flint 40·8—51·8% ; felspar 17·2—23·6% and whiting 7·2—10·0%.

COLOURS, DECORATIVE PROCESSES, ETC.

ON GILDING GLAZED WARE BY A BURNING-ON PROCESS.—P. P. Budnikoff (*Ber. Polytch. Ivanovo-Vosniessensk*, **6**, 211, 1922 ; abstract from *Chem. Zentr.*, **93**, 235, 1922). An effort has been made by the writer to work out methods for gilding glazed ware and to study them from a theoretical standpoint. Gold was precipitated by iron vitrol from aqua regia solution, ground with 8—10% of a flux consisting of 6 parts basic bismuth nitrate and 0·5 parts anhydrous borax, and mixed with oxidised turpentine and lavender oil ; the mixture was then applied to ceramic wares. After firing to 650—900°C. a brilliant gold surface was obtained. Brighter tints were produced by adding about 30% (of gold weight) of AgCl. Gilding can also be produced with sulphur balsam. 100 grs. of dry French turpentine, 20 grs. sulphur and 20 grs. Venetian turpentine are gently brought to boiling point in an oil bath, a long glass tube being used instead of a reflux condenser. Any acid formed must be distilled off from time to time, as it tends to hinder the reaction. It is advantageous to heat the mixture in a current of CO_2. To 8—9 parts of this balsam, a gold chloride ($AuCl_3$) solution (1 part gold, 4 conc. HCl, 4 HNO_3 diluted with water) is added and heated over the oil bath to dissolve the gold. After removing the water and drying the oil, the latter is mixed with 7—8% lavender oil and 12% French turpentine. The product of the reaction is dissolved in CS_2, filtered, and, after expelling the CS_2, mixed with 5—8% basic bismuth nitrate, then applied to clay ware and cautiously fired to 450—600°. A beautiful gilded surface is obtained by this method. An even better surface is obtained if a sulphur balsam, produced by the reaction between S_2Cl_2 and turpentine, is used.

ON APPLYING GALVANO-PLASTIC COATINGS TO CERAMIC WARES.—(*Tonwar. Ofen Ztg.*, **46**, 76, 1922)). In art ceramics the

process of applying a metallic lustre to clay products by means of a galvano-plastic deposit is becoming increasingly popular. Successful application of the process, however, demands careful attention to details; it is important, for instance, to fill up the body pores (with wax, etc.) in order to prevent blistering and scaling. To ensure a fast and durable metallic coating, the wax must then be covered with a conductive layer, usually of graphite. The best method of doing this is to apply a conductor which can be burned on. Such a process has recently been patented by a firm in Teplitz (Bohemia). A conductor is obtained by mixing birch oil, asphalt, petroleum and gold-graphite. This mixture is applied to the ware and fired on at 200°C. To prepare gold-graphite 2 grams of pure gold are added to gold chloride and mixed with a solution of 10 grs. potassium cyanide in 500 grs. distilled water. To this liquid 10 kg. of pure graphite are then added. The resulting gold-graphite mixture is thoroughly mixed in the proportion of 12·5 with petroleum ether, applied to the ware, and fired on at 200°C. This gives a coating of high conductivity, with consequent greater durability of the galvanised surface.

LIQUID GOLD.—P. P. Budnikoff (*Zeits. angew. Chem.*, **35**, 653, 1922). The subject is treated from the theoretical standpoint, mainly with reference to the nature of the gold compound on the finished product. The raw materials used in the ordinary process are: turpentine, lavendar and other oils, sulphur and gold chloride. The turpentine is heated for several hours with 20% sulphur on an oil bath with reflux condenser. Auric chloride is added to the product, a thick, homogeneous reddish-brown liquid containing sulphur compounds. A small quantity of H_2S is evolved during the reaction. About 50% of the turpentine remains in the fractionating flask in the form of a resin, which can scarcely be examined. It has not yet been found possible to separate from the products of the reaction a substance with a constant boiling point. A definite compound was, however, isolated by treating the distillate with methyl iodide. A fine, crystalline precipitate is formed, which can be dissolved in alcohol and precipitated by ether. This compound, according to analyses, has the formula: $C_{10}H_{16}SCH_3I$; it is a genuine sulphonium salt, and has, therefore, been given the name methyl-terpene-sulphonium-iodide. Treated with moist silver oxide, it forms a strong, soluble base which precipitates the heavy metals and which decomposes on boiling with water, a light-coloured oil (probably turpene sulphide $C_{10}H_{16}S$) being distilled over. These sulphur compounds constitute an important factor in sulphur balsam. With the salts of heavy metals in alcoholic solution, they form complex compounds, which are amorphous and unstable. On heating, or boiling with water, the sulphur separates out. If a precipitate is formed in this manner with gold chloride and applied to a glazed body, a gold surface is not obtained on firing. The grains of this product are probably too coarse to form a continuous film. In order to produce a satisfactory gold surface, a solution of gold chloride in water is treated with sulphur balsam. The gold chloride then combines slowly with terpene sulphides and goes into solution. No precipitate is formed and the gold compound remains in (apparently colloidal) solution. On heating to 250—300° in the muffle, a black coating of gold sulphide is formed, which on further heating yields sulphur dioxide and gold. Better results were obtained by treating the turpentine with sulphur chloride (S_2Cl_2) instead of with sulphur itself.

PLANT AND MACHINERY, ETC.

LATEST DEVELOPMENTS IN FINE GRINDING.—G. Glockemeier (*Met. Erz.*, **19**, 285, 1922). The principle of the tube mill, together with its later development, the shorter and wider ball mill, is first described. This is followed by a discussion of the various types of ball mills, including the ball mill with sieve, the overflow ball mill, Gröndal mill, Hardinge mill, and the Marcy mill. The article closes with a short account of the rod mill, or Marathon mill, in which the balls are replaced by steel rods. There are a number of illustrations.

A SWISS AUTOMATIC CUTTING TABLE.—(*Brit. Claywr.*, **31**, 115, 1922). An account is given (with illustration) of a brick-cutting machine, a special feature of which is that, when bricks are cut off, one at a time, and separated from the end of the clay column, they are grouped in pairs, or in threes.

AN AUTOMATIC BRICK-CUTTING MACHINE.—(*Tonind. Ztg.*, **46**, 1,062, 1922). A portable automatic brick cutter has recently been put on the market by the firm of L. Gnad, of Waiblingen. The clay column is received on 4 interchangeable plaster rollers, and the whole of the mechanism is driven from these rollers. By means of a lifting arrangement, the bricks, after cutting, are lifted 3 at a time and placed on 3 supporting rods, which are long enough to hold two lots of 3 bricks with a suitable space between each lot. This simplifies the removal of the bricks. To allow for irregularities in the speed of the clay column, a special coupling arrangement engages with the cutting mechanism, so that bricks of uniform size are cut off. There is also an arrangement for cleaning the wire after each cut.

Patents.

HANDLING BRICKS, ETC.—G. E. Luce (*Pat. J.*, 1,753, 1922). No. 182,180, Mar. 23, 1921. Bricks, fed continuously from a brick-making or like machine, are handled by a series of carriers, each of which is first moved against the direction of the feed of the bricks to engage a load, and then retracted at a speed not less than that of the travel of the bricks.

TURNING POTTERY.—E. Brookes (*Pat. J.*, 1,754, 1922). No. 182,707, July 29, 1921. A machine is described for trimming and rounding off the edges of pottery articles such as cups, etc. (2 sketches).

FILTER PRESSES.—J. Newton (*Pat. J.*, 1,759, 1922). No. 184,426, Feb. 17, 1922). The wood trays of slip presses are provided with metal shoes, so that the thickness of the trays will not vary on account of swelling of the wood, and the alignment of the nozzles on the supply pipe with the joints of the trays will be preserved. The shoes may extend for the whole length of the top or bottom edge, or both, or may take the form of short lengths spaced apart.

FILTER PRESSES.—A. T. Stuart (*Pat. J.*, 1,761, 1922). No. 185,116, Aug. 22, 1922. Frames for filter presses comprise outer rims and a number of thin strips spaced apart as by washers on cross-bolts. The cloth on both sides of the frame is supported by the edges of the strips.

MACHINE FOR MOULDING RIDGE TILES, ETC.—E. Hodgkinson (*Pat. J.*, 1,764, 1922). No. 185,824, June 9, 1921. Relates to improvements in machines for making ridge, lip, and valley tiles, etc. The material is passed between a pair of shaping-rolls and is severed by a knife.

DISINTEGRATORS.—Plauson's (Patent Co.) Ltd. (*Pat. J.*, 1,764, 1922). No. 185,878. In high-speed rotary disintegrators (*Spec.*, 176,002) one or more baffle-plates are used to check the formation of eddy currents.

CRATES.—J. Gould (*Pat. J.*, 1,765, 1922). No. 186,237, Aug. 30, 1921. A crate for packing pottery consists of vertical staves, so closely arranged that the hand cannot pass between them, and connected to top, bottom, and intermediate headings. The staves pass through holes in the headings and are secured to the bottom members by withing.

POTTERS' LATHES.—W. C. Minshall and H. Thompson (*Pat. J.*, 1,767, 1922). No. 186,667, June 23, 1921. The lathe spindle, which is in one piece, is mounted in detachable ball or roller bearings, enclosed in a dust-proof housing comprising two separable discs fixed to the frame.

III.—FINISHED PRODUCTS: TESTING, ETC.

NOTES ON SHIVERING OF TERRA-COTTA.—J. L. Carruthers (*J. Amer. Cer. Soc.*, **5**, 518, 1922). The results obtained by previous investigators are reviewed. This is followed by an account of investigations on body constituents, undertaken for the purpose of fitting the body to the glazes in use. Six terra-cotta clays were tested for shivering,—a white matt glaze being used for the purpose—and from these six, one non-shivering and one badly shivering clay were chosen for experiments for producing and overcoming shivering. Test pieces of a shape peculiarly susceptible to shivering were pressed in plaster moulds. The results of a large number of tests indicate that shivering in terra-cotta bodies is caused or promoted by one or more of the following ; (1) The presence of a highly siliceous clay in the body, (2) the presence of considerable finely-ground grog of a siliceous nature ; (3) the presence of soluble salts in the clay, grog, or in the water used for tempering. Three methods of eliminating shivering in terra-cotta bodies, if due to one of the above causes, are suggested by this work and that of others, namely : (1) shivering caused by the presence of siliceous material in the body may be overcome by the use of (*a*) felspar, felsite, or rock of similar composition, making the body more dense, *i.e.*, use a flux in the body ; (*b*) coarse sand or grog, making the body more open. (2) Shivering caused by soluble salts can be eliminated by the use of barium carbonate.

NOTES ON GREEN STAINING OF CLAY WARE.—C. W. Hill (*Bull. Amer. Cer. Soc.*, **1**, 51, 1922). Hill disputes the view, almost universally held since the time of Seger, that the yellow-green staining which sometimes occurs on ceramic products on exposure to weather is due to compounds of vanadium. A sample of such a stain, from a clay which was known to contain some pyrites, was digested with various acids but the solution failed to give a test for iron. The dried stain was then fused with an alkali and dissolved in HCl. This solution gave a heavy iron test. Upon neutralization with ammonia, a white flocculent precipitate was obtained, indicating that the iron had been combined with alumina or silica. The writer, therefore, concludes that it is advisable to test for iron by fusion before assuming that vanadium is the cause of any green stain.

SOME EXPERIMENTS ON THE FIRE-CRACKING OF TERRA-COTTA.—E. C. Hill (*J. Amer. Cer. Soc.*, **5**, 299, 1922). Firecracks, cooling cracks, or dunting, occur under certain conditions in terra-cotta ware, and are caused by contraction strains set up in the body during cooling. Pieces set in projecting or exposed positions are usually most prone to develop this defect, particularly when placed so as to be subjected to the direct rays of the sun. While the effect of the rate of cooling on the tendency of bodies to firecrack is generally understood, there is a wide difference of opinion with regard to the composition and physical properties of the body. With a view to obtain some data on this question, the author conducted experiments (in three series). Large typical pieces of terra-cotta, made from various clays and grogs, were fired, and cooled at different rates, the tendency to firecrack being observed after lengthy weathering periods. The absorption, porosity, and transverse strength of the various bodies were also determined. *Rate of Cooling.* All bodies similar to commercial types showed a tendency to crack when cooled rapidly and all were free from cracks when cooled slowly. The rate of cooling has a much greater effect on the tendency to firecrack than the composition or physical properties of the body. *The Effect of the Clay.*—Sandy clays were more liable to fire-cracking than vitrifying clays. This is probably due to the difference in the expansion and contraction of sand and clay. The presence of sandy material and the character of the clay itself appear to have a much greater effect on the tendency to fire-crack than the absorption, porosity or the transverse strength of the body. No relation was found to exist between the porosity and transverse strength of a body

and its tendency to fire-crack. *The Effect of Grog.*—The size and amount of grog was found to be the important factor. The kind of grog is of much less importance in this matter than the kind of clay. An increase in the quantity of grog reduced the tendency to fire-crack. A body with all grog finer than 40-mesh was the worst from the point of view of fire-cracking, though one with all grog coarser than 40-mesh was little better than the average.

THE TENSILE STRENGTH OF PORCELAIN.—F. H. Riddle and J. S. Laird (*J. Amer. Cer. Soc.*, **5**, 385, 1922). The machine used in the experiments described in the paper is an ordinary 2,000-lb. Olsen cement-testing machine provided with special grips. It is both small and inexpensive. Two types of test specimens were used in the investigations : No. 1 had conical ends or shoulders making an angle of about 15° with a straight portion in the centre ; No. 2 was dumb-bell shaped, the diameter of the ends being about twice that of the central portion. Both types were designed to be held in the jaws of the machine so as to eliminate as far as possible transverse stresses and excessive local stresses which would tend to produce shattering. The test specimens were prepared by pugging and extruding rolls of suitable size, throwing these by hand, or by cutting blanks from large pugged and cast blocks. It was found that specimens prepared in different ways showed different strengths. The minimum cross-section of the test pieces varied between 0·125 and 0·2 sq. in. The results of a typical series of tests on specimens formed by pugging (about 20 being tested in each case) are given in the following table:

Test specimen	Aver. cross-sect. area., sq. in.	Aver. load lbs.	Aver. strength, lbs. per sq. in.	Variation per cent. Aver.	Max.
		Triaxial	Porcelain		
No. 1 (conical) ..	0·131	816	6249	15·0	39·7
No. 2 (dumb-bell)	0·127	731	5760	15·6	23·2
		Special	Porcelain		
No. 1 (conical) ..	0·129	1320	10250	17·7	37·9
No. 2 (dumb-bell)	0·130	1211	9390	15·1	33·9

The consistency shown by the results indicated that this method gives an accurate measurement of the relative strengths of different porcelains. Good triaxial porcelain was found to have a strength of 3,000 to 6,000 lb. per sq. in. Special high temperature porcelains showed strengths up to 10,000 —12,000 lb. per sq. in. A comparison of tensile with compression strengths gave an average ratio of 1 : 5·9 for the special porcelain, and 1 : 7·66 for the triaxial porcelain.

THE FLASH-OVER STRENGTH OF PORCELAIN.—A. Schwaiger (*Elektrotech. Zeits.*, **43**, 875, 1922). Investigations were carried out, the object of which was to determine the flash-over strength of porcelain. It is maintained that the flash-over in air is the same as breakdown in air and that the two obey the same laws.

MICROSCOPIC INVESTIGATIONS ON SAND-LIME BRICKS.—H. Hirsch (*Tonind. Ztg.*, **46**, 1,185, 1922). The literature on the subject is first briefly reviewed. The author tested the chemical and mechanical properties of a number of commercial bricks made by different processes, *e.g.*, cylinder slaking with a portion of the sand present, silo slaking after mixing the whole of the sand and lime, and hot slaking of the sand-lime mixture in a steam-heated cylinder. In all cases the sand and lime were slaked together ; the pre-hydrating process is not represented, since it has to a large extent been abandoned owing to unsatisfactory results obtained in practice. The inferiority of this method is, however, disputed by the writer, and to test the

assumption, he carried out a parallel series of experiments on bricks made by the pre-hydrating and the silo slaking methods. The data obtained both with the laboratory and the commercial bricks are tabulated. The materials were also examined microscopically in thin section. Under the microscope, the following factors are usually perceptible : the degree of mixing, the break-up of the quartz particles, and the formation of new compounds, such as the crystalline cement surrounding the quartz particles. Examination of the thin sections showed in particular that the formation of these new crystalline structures was not dependent upon the method of manufacture. The sand appears to be the main factor in determining the quality of a brick. Microscopic examination indicates whether, and to what extent, impurities or any lack of uniformity occur in the body. It shows the degree of mixing and binding, the bedding of the different constituents and finally, to some extent, the nature of the cementing material.

HEAT TRANSMISSION, WITH SPECIAL REFERENCE TO THE STOKER-FIRED BOILER.—R. M. Howe and S. M. Phelps (*J. Amer. Cer. Soc.*, **5**, 420, 1922). The forced draught automatic stoker is one of the results of the universal effort to burn coal more economically. By the use of this apparatus, the efficiency of a low-grade coal has been increased from 50 to 65 per cent. It has been noted, however, that the pressure induced within the furnace by this system has a deteriorating effect on the refractories. This phenomenon is the subject of this paper. Fireclay tiles were made so that temperature readings could be obtained at several distances from the hot surface. These tiles were placed in the door of a furnace, laid up with fireclay, and heated, the proper draught and pressure being of necessity maintained under laboratory conditions.

TABLE. 1.

Furnace Temperature.	1,340°C.	1,340°C.	1,340°C.	1,220°C.	1,220°C.	1,220°C.
Pressure of furnace gases (inches of water)	+1·00	+0·05	−0·30	+0·95	+0·05	−0·30
Temp. of firebrick—						
½ in. from hot surface	1305	1265	1105	1105	1075	900
1 ,, ,, ,, ,, ..	1270	1210	1020	1035	965	800
2 ,, ,, ,, ,, ..	1125	1040	800	900	770	620
3 ,, ,, ,, ,, ..	1040	950	720	800	660	490
4 ,, ,, ,, ,, ..	845	745	515	665	510	355

An examination of the above data brings out the fact that heat penetration depends very largely upon the pressure of the furnace gases. It is not only a function of the thermal conductivity of the brick, but also of its permeability. The temperatures recorded under a draught of −0·30 in. of water show the cooling effect of cold air that was drawn from outside through the brickwork into the furnace. On the other hand, when the furnace gases are under pressure, they penetrate the brickwork, impart their heat, and raise the temp. above that which would result from simple thermal conductivity. Spalling is, therefore, associated also with furnace pressure, since the latter accelerates vitrification; for, as firebricks vitrify, they become less resistant to temp. change and spall more readily. It is suggested that spalling may be decreased by applying a thin wash of dense-burning cement to the entire furnace lining. When this vitrifies, or melts, it retards gas penetration and

thus maintains a lower temp. within the brickwork. The results obtained have a direct bearing upon the study of thermal conductivity. The heat transmitted through a refractory depends upon at least two factors—the thermal conductivity of the material itself and the penetration of hot or cold gases. Heat transmission is greater or less than thermal conductivity when hot or cold air is drawn through the specimen under investigation. They also throw an important light upon the action of slag on fire bricks. The slag will obviously penetrate only to a slight extent before it becomes chilled. Before going further it must dissolve the brickwork. Its action is, therefore, primarily a function of its fluxing power. Results obtained by treating a brick, heated throughout, with a small quantity of slag, have no practical value, for they measure penetration rather than chemical action.

TESTING REFRACTORY BRICKS.—(*Kalk. Schm. Ztg.*, **29**, No. 16 1922). A standard, universally recognised method of testing refractory bricks is not yet available. According to Canaris, the most important properties of refractory bricks are: (1) exterior form; (2) chemical composition; (3) melting point; (4) shrinkage and expansion; (5) resistance to temperature changes; (6) brittleness and crushing strength at ordinary temp.; (7) strength and carrying capacity at high temperatures (softening point); (8) porosity; (9) resistance to molten slag and metals; (10) resistance to gases; (11) thermal conductivity and impermeability to gases; (12) microstructure. The usual methods of testing these properties are briefly described. Canaris lays special stress on the fact that single bricks behave in a totally different manner under the tests than a complete wall constructed of the same type of brick.

REFRACTORIES—WITH SPECIAL REFERENCE TO RECENT DEVELOPMENTS.—W. F. Rochow (*Ceramist*, **1**, 181, 1921). A general account is given of various refractories, their manufacture, properties, and application in industrial practice.

Silica Bricks. Approximately 80% of the silica brick produced in the U.S.A. is made in Pennsylvania. The only rock used is a lime quartzite, commonly called ganister or silica rock. A typical analysis is as follows: SiO_2 97·75; Al_2O_3 ·95; Fe_2O_3 ·90; CaO ·10; MgO ·20; alkalies ·25, total 100·15. The fineness of the grind varies from 60% through a six-mesh to 100% through a ten-mesh screen, depending upon the purpose for which the bricks are to be used. As the grinding proceeds, 2% of lime is added as milk of lime. Less than 1·4 or 1·5% of lime makes a mechanically weak brick, while much more than 3% may lower refractoriness appreciably. Drying is accomplished in 3 to 4 days at a temperature of 200 to 400°F. The bricks are then set in a down-draught kiln and burned, usually with soft coal. From 9 to 12 days after the commencement, the kiln should have attained its maximum temp. in front of the fire box. A soaking heat at the highest temp. is maintained for another day. Cooling requires about as much time as the firing.

Properties of Silica. As determined by Fenner, the inversion of quartz to tridymite begins and proceeds slowly, at 870°C., in the presence of a flux. In the absence of a flux, the inversion commences at 1,470°. The effect of longer periods of burning (from one to six times under industrial conditions) is shown in the following table (McDowell):

Grind	Burned to Cone	No. of Burns
Reg.	15	1
,,	16	3
,,	14	4
,,	15	6
	Constitution in per cent. by volume.	
Quartz & Silicates	Tridymite	Cristobalite
26	4	70
16	19	65
12	30	58
12	45	43

All burned silica bricks expand temporarily on heating in accordance with the true thermal expansion of the several crystalline forms. The very rapid expansion of crystobalite at 230°C. and of quartz at 570° account for the spalling tendency of silica bricks when subjected to sudden changes of temperature (Le Châtelier). A means of measuring the spalling tendency recently devised, consists in heating the brick at a uniform rate of 15°C. per hour to 600°. The bricks are then withdrawn from the furnace and allowed to cool rapidly in air, free from draughts. The cross breaking strength of representative specimens is determined before and after the heat treatment and the spalling tendency is calculated as the loss in strength. Silica bricks are now widely used in the U.S.A. in by-product coking practice. They are used entirely in that part of the coke oven above the floor line, with the exception of the facings. Their high thermal conductivity has enabled the coking period to be decreased considerably, and they are not appreciably affected by the carbonizing gases.

Silica Bricks for Lime Kiln Linings. At the temperatures required for calcining limestone, no reaction takes place between the lime and the silica. If precautions are taken to prevent spalling through sudden changes in temp., many lime kilns can be operated with less repair costs and with material economies when silica is used instead of a first quality firebrick lining. In many instances, the service has been increased from 100 to 300 per cent. With proper care, silica bricks are also giving greatly increased service as linings for rotary dolomite kilns.

Silica Bricks in Muffle Furnaces. Remarkably uniform heating, with the maintenance of a lower temp. outside the muffle, is obtained with silica bricks used in certain parts. The bricks do not deteriorate under the action of the gases, and, owing to the property of expansion, they do not allow the gases to leak into the muffle.

Clay Refractories. A comparatively recent departure in the manufacture of clay firebricks has been the development of the machine-made product. A machine-made brick is considerably denser, of more uniform grind and truer to its dimensions. It is consequently better able to withstand abrasion and is also more impermeable to gases and liquid fluxes. In boiler furnaces, for instance, the clinker is less likely to adhere to machine-made bricks, and in the crucible and hearth of frit furnaces, etc., they give longer service than the hand-made product.

Developments in the Testing of Clay Refractories. These are discussed briefly.

For making all-clay steel melting crucibles, English Stourbridge and Stannington clays were used almost exclusively in America, but recent trials have proved that good results can also be obtained from a mixture of Ohio and Pennsylvania clays.

Carbon or Graphite Refractories. The American industry has been dependent entirely upon imported raw materials for these products. Artificial graphite has been found unsuitable, and no substitute for Ceylon graphite is available. The same applies to the German Klingenberg clay, the peculiar property of which is its wide range of vitrification.

Basic Refractories. Prior to the war, Austro-Hungarian magnesite was used almost exclusively, but good results have been obtained with the Grecian variety; and by proper selection and treatment, some American magnesites have given highly satisfactory results. Dolomite, which is comparatively high in lime, has never yet been used successfully.

Patent Metalkase Magnesia Brick. In the manufacture of this product, rectangular soft steel containers are rammed full of ground calcined magnesite. For best results, there must be a close relation between the weight of the magnesite and of the metal employed. No cement is used in laying the bricks. Trials extending over more than a year have clearly demonstrated a number of advantages of the metal case bricks, over magnesia bricks. At the furnace temperatures, the metal fuses back about the distance of an inch from the heated surface, the metal penetrating the magnesia and making a

monolithic structure. This makes the lining slightly more porous, which probably explains the improved resistance to spalling. The widest application of this type of brick has been in the basic open hearth furnace. They have been the means of greatly increasing the service in the entire back wall, and they have also proved much superior to silica bricks in the bulkheads. Speaking generally, the use of metalkase bricks in certain parts of the furnace, promises an increased life of from 15 to 25 times that of silica, and about 3 times that of magnesia bricks.

Bauxite Bricks. These have been widely used in the lining of rotary kilns for burning Portland cement. Basic clinker will not flux with, nor adhere to, the bauxite lining because of its basic nature and great density.

REPORT OF WORK ON THE RAW MATERIALS AND THE MANUFACTURE OF SILICA BRICKS.—F. Cellerier (*Rev. Mat. Constr. Trav. Pub.*, No. 154, 106 B, 1922). As the result of investigations on refractories undertaken at the instigation of the French Ministry of Munitions, the following general conclusions regarding silica bricks were arrived at: (1) petrographic examination is necessary in order to determine the nature and physical characteristics of the raw material; (2) there is, in most cases, agreement between the deductions obtained from the petrographic examination and the results of burning tests; (3) physical and mechanical tests are necessary to supplement the petrographic examination; (4) the raw materials which appear to warrant investigation are the quartzites, particularly those with a microcrystalline matrix; (5) the maximum absolute density of good silica bricks is generally 2·40 before firing, and 2·35 after two burnings at 1,600°C., although these figures are exceeded in certain special types; (6) the absolute density of good bricks after two firings at 1,600° is usually in the neighbourhood of 2·31 as the result of the complete transformation of the silica; (7) the apparent density of good bricks is generally not less than 1·65, but this does not appear to be a fixed limit; (8) the relative porosity is sometimes high (17·9%) and sometimes low (9·8%). No definite conclusions can be drawn; (9) on the other hand, the relative porosity after two firings at 1,600° is only 1 to 3% for good bricks, and 6 to 7% for bad bricks; (10) the absolute porosity varies only slightly and serves no useful purpose; (11) the fusion temp. of bricks for Martin furnaces should be not less than 1,710°; (12) for good bricks, the silica content should not be less than 95%; (13) the determination of the proportion of sulphates only gives a partial guarantee of infusibility; (14) if, after two firings at 1,600° (or one at 1,700°), the expansion is considerable, the brick is bad. The expansion should be strictly limited to not more than 2 to 5% (2·5% ?); (15) the cold crushing strength should not be below 150 kg./cm² for good bricks, and 75 for bricks of second quality; (16) the crushing strength at 1500° on cubes 2 cm. square, after 2 burns at 1,600° or one at 1,700°, should not be less than 40 kg./cm² for good bricks.

THE FIRING TEMPERATURE OF MEISSEN PORCELAIN.—(*Zeits. angew. Chem.*, **35,** 651, 1922). A further, short discussion between A. A. Klein and W. Funk (see TRANS., **21,** 52A, 1922).

DUTCH KLINKER BRICKS.—(*Brick Pot. Tr. J.*, **30,** 286, 1922). The method of manufacture is briefly described, and the quality and appearance of the bricks are compared with Staffordshire blue bricks.

TENTATIVE SPECIFICATIONS FOR BURNED BRICKS.—(*Allg. Tonind. Ztg.*, **41,** No. 46, 1, 1922). Prepared by the Standardisation Committee of the German Brick Industry Association in Czecho-Slovakia. *Size and shape*: 25 × 12 × 6·5 cm. rectangular. *Varieties*: (1) clinker; (2) hard; (3) ordinary; (4) soft. The following maximum variations in size are allowed: ±3% in the length, ±4% in the width, ±5% in the height. The *porosity* (water absorption) for the 4 varieties is as follows:

		Average	Maximum in single specimens
1.	Clinker ..	below 5%	7%
2.	Hard ..	,, 5–12%	15%
3.	Ordinary ..	,, 12–20%	24%
4.	Soft ..	Above 20%	unlimited
		Strength	
		Average	Minimum in single specimens.
1.	Clinker ..	above 500 kg./cm².	400 kg/cm².
2.	Hard ..	,, 300 ,,	240 ,,
3.	Ordinary ..	,, 150 ,,	120 ,,
4.	Soft ..	,, 100 ,,	80 ,,

The methods of testing are briefly outlined.

TESTING THE HARDNESS OF REFRACTORY MATERIALS AT HIGH TEMPERATURES.—E. Rengade and E. Desvignes (*Chaleur et Industrie*, **3**, 965, 1922). A method is described for testing the hardness of refractory materials at high temperatures analogous to the Brinell test, a 90° cone being substituted for the ball used in the latter test. The test piece, cylindrical in form and 50 to 60 mm. in diam., is placed in the middle of an electric furnace (Rosenhain type) on a graphite support, pressure being applied by means of an amplifying lever through a rod of Acheson graphite, to the extremity of which the cone is attached. The temperature is read by means of a Leeds and Northrop optical pyrometer. After each experiment, the depth of the impression made by the cone in the test piece is measured with a small rule, the end of which is shaped to a point of 90°. Six bricks of refractory clay of different qualities and one bauxite brick were tested. The hardness was found to decrease progressively with a rise in the temperature, confirming the previous results of Le Châtelier, Bogitch and Endell. It also appears to diminish according to a definite law, but with a variation in the temperatures amounting to 250° between the two extreme bricks. There is no relation between the hardness at high temperatures and the fusion temperature as determined by cones. With regard to the chemical constituents, the alumina content does not appear to have any effect on the hardness. The presence of alkalies seems to have a much more marked effect. The best samples contained only traces of alkalies. It is concluded that, with an alkali content of 1 per cent. and over, the hardness at high temperature is adversely affected to a marked degree.

CHROME BRICKS.—R. E. Griffith (*Brick*, **61**, 180, 1922). There are very many different grades of chrome ore, and a high percentage of chromium oxide is no guarantee of the suitability of an ore. In some cases, a chromic oxide content of 52% gave no satisfaction, owing partly to a very high iron content. The hard ores containing 45 to 50% of chromic oxide, low iron and well balanced proportions of silica, magnesia and alumina are by far the most desirable. The annual consumption in America of one such brand is more than three times the tonnage of any other one grade. Chrome bricks are now available in America in unlimited quantities, which will analyse 47 to 50% of Cr_2O_3; they have much greater strength under load at high temperatures than was previously thought possible and are more resistant to slag penetration and less sensitive to temp. changes than magnesite bricks.

HARD-FIRE PORCELAIN AND HIGH-TENSION INSULATORS.—R. M. Friese (*Dinglers Polytech. J.*, **337**, 109, 1922). The chemical comp. and the method of manufacturing porcelain are briefly discussed. High-tension insulators are of two varieties: (1) the upright, rigid type and (2) the suspension type. The first have to resist pressure whilst the latter are subject to tension. The rigid insulators can be used up to 40,000 V., but above this the suspension type is usually employed. In the latter, the parts are of such dimensions that their break-down strength is always greater than their flash-over tension in air when dry. Under electric tension, an insulator exhibits a surface leakage current, a leakage current through the body and

a charging current. The surface current depends upon the condition of the glaze and is practically independent of the porcelain body. On the other hand, the current through the body is dependent on the nature of the body. Good porcelain has an exceedingly high resistance—at 20°C. about 10×10^{10} megohm/cm. The charge current depends upon the "condensing capacity" of the porcelain. The capacity of a rigid insulator is about 25 to $35 \cdot 10^{-6}$ mfds., and of each member of a suspension insulator 35 to $55 \cdot 10^{-6}$ mfds. in a dry condition. An insulator for 40,000 volts (dry) has an apparent consumption of about 14 volt-amps. with an actual efficiency loss of 1·6 watts. Porcelain does not "age," or become inferior in quality with time, but to ensure durability of insulators, the coefficient of expansion of the cement used must be reduced to approximately that of the porcelain by the addition of shortening media (quartz, etc.), to the pure cement. An insulator has the highest flash-over value in a dry condition. In wet weather, the value decreases according to the strength, direction and conductivity of the falling rain. Each member of a chain of insulators constitutes a "condensor," but the total tension in such a chain is not equally divided between the members; those nearest to the cable have to support the greater portion of the tension. In the following average values, E = the total tension of a chain between cable and support (= 100); E_n = the tension at the base of the nth member from the support; e_n = the tension between the cap and base of the nth member, and n the number of the member counting from the support.

n =	1	2	3	4	5	6	7	8
E_n =	7·5	13·5	20	28	38·5	52·5	71·5	100%
e_n =	7·5	6	6·5	8	10·5	14	19	28·5

CLAY *v.* CAST IRON PIPES.—(*Brit. Claywr.*, **31**, 150, 1922). Laboratory tests have been made at the Carnegie Institute, Pittsburgh, and it is claimed that bituminous clay pipe for drainage and sewerage is in every way equal to the more expensive cast-iron pipe. The problem of a satisfactory jointing material is claimed to have been solved.

BRICKS FOR FORGES AND ANNEALING FURNACES.—(*Brit. Claywr.*, **31**, 154, 1922). The roof and sides of forge furnaces should be built of bricks which are fairly coarse in texture and fairly porous, so as to resist sudden temp. changes to which they are subjected. Well-burned fireclay or grog bricks are the best. In the hearth and the lower portions of the sides, the bricks must also be resistant to corrosion and abrasion; they should, therefore, be fine in texture and rather dense on their surface, but with a porous interior.

BRICKS FOR CRUCIBLE FURNACES.—(*Brit. Claywr.*, **31**, 224, 1922). The chief causes of failure in the lining of crucible furnaces are: (*a*) the corrosive action of the ash in the fuel; (*b*) the abrasion of descending fuel; (*c*) the strains set up by sudden temp. changes; (*d*) partial fusion of the refractory materials. The bricks best suited to meet these requirements in different parts of the furnace are indicated. The jointing material should depend on the nature of the bricks used.

MECHANICAL PROPERTIES OF REFRACTORY MATERIALS AT HIGH TEMPERATURES.—P. Frion (*Cer.*, **25**, 308, 1922). A communication dealing with this subject was presented by E. L. Dupuy, Director of the Laboratories of the Saint-Jacques Works, Montluçon, at the International Scientific Congress held at Liège. The author confined his attention to refractories of the silico-aluminous variety. The apparatus used for crushing strength tests was similar to that described by Le Châtelier and Bogitch, except that an electric resistance furnace was substituted for the gas-fired type. The maximum resistance at about 1,000°C., found by previous investigators, was confirmed by Dupuy, but he also noted that the samples, after having been crushed at this temp. resumed, on cooling, a certain degree of solidity, thus indicating that a portion of the constituents had undergone fusion during the test. The phenomenon observed is explained on the

"skeleton" theory of refractories, in support of which experiments were carried out in which the pressure was applied at varying rates: (1) charge applied at the rate of 150 kg. per min.; (2) charge applied at the rate of 11·25 kg. per min.; (3) static charge applied to produce 15% subsidence of the sample in 15 minutes.

A SIMPLIFIED METHOD OF DETERMINING THE DRY VOLUME OF CLAY BRIQUETTES.—J. L. Crawford (*J. Amer. Cer. Soc.*, **5**, 394, 1922). The paper describes how the standard method of the Amer. Cer. Soc. and of the A.S.T.M. can be simplified in order to eliminate the oil saturation and lessen the number of weighings, since it is often extremely difficult to remove the last traces of kerosene from the products. Four or five extra briquettes are therefore made, weighed dry, and saturated with kerosene. Their volumes are determined in the usual way, and the bulk specific gravity from formulae. The remainder of the test pieces are simply weighed dry and their volumes are determined by dividing the dry weight by the bulk sp. gr. Some data are tabulated.

THE THERMAL CONDUCTIVITY AND POROSITY OF REFRACTORY BRICKS.—W. Ritter (*Feuerung*, **11**, 7, 1922). A résumé of Vologdine's work.

THE DISCOLORATION OF BRICKS.—(*Brick Pot. Tr. J.*, **30**, 183, 1922). A short résumé of the usual causes of "scum," "wall-white," etc.

NOTE ON THE CAUSE OF THE SPLITTING OF A POTTERY BODY.—(*J. Soc. Chem. Ind.*, **41**, 329T, 1922). See TRANS., **21**, 72 (A), 1922.

ELECTRICAL PORCELAIN RESEARCH.—M. H. Hunt (*Electr. World*, **79**, 966, 1922). Abstract from *Electr. Journal*. Research work in this subject usually includes the following considerations: (1) properties of the various ingredients in a porcelain body; (2) properties of the body as a whole in the plastic state, including shrinkage, cracking and strength; (3) burning behaviour (cracking, vitrification, shrinkage, sp. gr. changes, colour, etc.); (4) properties of the fired porcelain (impact, tension, compression, shear, thermal expansion, etc.). The means for carrying out these various tests are described.

SOLUBLE SALTS IN CLAY WARES.—C. W. Parmelee (*Brick*, **61**, 249, 1922; *J. Amer. Cer. Soc.*, **5**, 538, 1922). The need for standardisation of the terms employed is pointed out and the following classification suggested: (1) *Efflorescence*—to include soluble salts upon clays, dryer or dry house white, kiln white (certain forms), and wall white; (2) *Scum*—to cover dryer white due to the action of waste gases, kiln white (except that produced during the water-smoking) and certain forms of wall white (deposits of volatile substances on the surface). These items are discussed in some detail from the point of view of causes, occurrence and proposed remedies. A full list of references is given.

NEW HIGH-TENSION INSULATOR.—L. Perrin and E. Piernet (*Rev. Gén. d'El.*, **11**, 716, 1922). The new type provides for more nearly uniform distribution of potential in any chain of suspension insulators.

IV.—MANAGEMENT, ORGANIZATION, COSTING, ETC.: COMMERCIAL.

CLAY STATISTICS, 1921.—(*China Rev.*, **5**, 76, 1922). Statistics from the Board of Trade Annual Statement.

REDUCTION OF INDUSTRIAL WASTE.—D. T. Farnham (*J. Amer. Cer. Soc.*, **5**, 440, 1922). A discussion of a Report issued by the Federal American Engineering Society (see TRANS., **21**, 125A, 1922).

COSTING "ODD STUFF."—(*Brick Pot. Tr. J.*, **30**, 255, 1922). Details of cost are often overlooked, and guess work has to be resorted to in estimating prime costs. The basis of all systems of costing is a sheet or card, supplied to each worker, on which he writes what has been done during the day, the time spent on the work, and the quantity of materials employed. The various items relating to one lot of articles, or to one order, are then collected on a single sheet, from which the cost is easily obtained. A special sheet must usually be reserved to take care of rent, rates, taxes and general office and selling expenses.

THE DETERMINATION OF PRIME COSTS IN BRICK AND TILE WORKS.—(*Rev. Mat. Constr. Trav. Pub.*, No. 156, 129B, 1922).

CERAMICS IN AUSTRALIA.—(*Rev. Mat. Constr. Trav. Pub.*, No. 156, 134B, 1922). A somewhat lengthy extract from a detailed Report by the French Consul at Sydney, dealing with : clays and colours ; local industries ; export and import statistics ; the various articles manufactured ; tariffs.

NOTE ON REFRACTORIES ENGINEERING.—W. E. Dornbach (*Bull. Amer. Cer. Soc.*, **1**, 43, 1922). A brief outline is given of the training necessary to fit a person for work as a refractories engineer. Up to the present time, the work has been mainly of a consulting nature, but a wider scope is now being given to the profession. Large refractories manufacturing concerns employ refractories engineers to work out difficult refractories problems that cannot be definitely solved in the laboratories. As an illustration of the importance of the subject, the writer gives details of a recent experience of one of the most competent American engineers. A large copper refinery had been using a reverberatory fired by hand with coal by means of a Dutch oven. The heat in the reverberatory was about 2,600°F. under this process. The bottom was of silica sand, the side walls of magnesite bricks and the roof was laid up of heavy silica shapes making it 20 in. thick. The company found that, by eliminating the Dutch oven and by feeding powdered coal direct to the reverberatory, they could make one furnace take the place of four, and at the same time save 28% of fuel. The result was that the furnace temperature rose from 2,600° to about 3,200°F. and the heavy silica roofs quickly burned out. Furthermore, where the silica bottom and the magnesia bricks came in contact the latter rapidly disintegrated through the attack of the silica at the higher temp. The refractories engineer who was called in, quickly diagnosed the trouble and prescribed the cure. A thinner roof was recommended, namely, one of 12" shapes, to allow thorough radiation, thus lengthening the life of the silica bricks in the crown. A magnesite bottom was recommended and installed. This not only stopped the disintegration of the magnesite bricks, but it also saved the company an immense amount of money for metallurgical reasons. A purer product resulted, entirely eliminating the use of a blast furnace later in the process.

POTTERY MANUFACTURE IN THE EAST LIVERPOOL DISTRICT (U.S.A).—C. H. Jones (*Chem. Met. Eng.*, **26**, 346, 1922). A well illustrated account of the plant operations in the manufacture of semi-vitreous china at Plant No. 5 of the Homer Laughlin China Co.

ELECTRICAL PORCELAIN MANUFACTURE.—C. H. Jones (*Chem. Met. Eng.*, **26**, 438, 1922). A description—well illustrated—of the plant of R. Thomas & Sons at East Liverpool, Ohio.

"SIMPLIFICATION" IN CLAYWORKING.—(*Brit. Claywr.*, **31**, 122, 1922). The advantages and disadvantages of "simplification" in the clay-working industries are pointed out.

CHINESE CLAYS FOR EXPORT.—(*Brick*, **61**, 562, 1922). Investigations were carried out by J. M. Clements, of the U.S. Department of Agriculture, into the possibility of obtaining supplies of high-grade kaolin from China with a view to a reduction in prices prevailing in the U.S. for pottery. The deposits from which kaolin is obtained to produce Chinese porcelains are

not conveniently situated for export. The deposit most favourably situated for this purpose is in the province of Kwangtung, in which locality there is no pottery industry.

V.—GLASS: GENERAL.

THE PERSIAN GLASS INDUSTRY.—Badermann (*Glas. Ind.*, **33**, 293, 1922).

OPTICAL GLASS. (*Glas. Ind.*, **33**, 294, 1922). Mainly a historical survey.

QUARTZ GLASS.—G. Flusin (*Verre*, **2**, 193, 1922). Continuation. The manufacture of the opaque variety, methods of fusing, types of furnaces, etc., are dealt with. *Ibid.*, p. 217. Methods of moulding and shaping are described. A description is given of semi-translucent and transparent quartz glass.

THE INDUSTRY AND COMMERCE OF GLASS IN CANADA.—L. van Aken (*Verre*, **2**, 199, 1922).

A PNEUMATIC BLOWPIPE.—(*Verre*, **2**, 225, 1922). A description, with two illustrations, of the apparatus patented by W. Lippold. The blowpipe is of simple construction. The handle, or grip, is filled with compressed air, controlled by a piston and a helical spring. The pipe is manipulated exactly like the ordinary type, but instead of blowing into it, the workman releases the supply of compressed air by applying pressure to the piston with his thumb.

"PYREX" GLASS.—P. E. Erckmann (*Chim. Ind.*, **8**, 785, 1922). A review of the leterature on the subject. (9 illustrations).

MODERN GLASS FACTORY EQUIPMENT.—W. S. Mayers (*Glass Ind.*, **3**, 197, 1922). The furnace, cooling systems, fans, etc., are discussed.

GAS-PRODUCERS AND FURNACES IN THE GLASS INDUSTRY (Contd.).—R. Schneider (*Glas Hütte*, **52**, 673, 1922). A description is given of a Siemens regenerative gas furnace with open pots and slotted burners (4 illustrations).

THE DIFFUSION OF HYDROGEN AND HELIUM THROUGH SILICA GLASS AND OTHER GLASSES.—G. A. Williams and J. B. Ferguson (*J. Amer. Chem. Soc.*, **44**, 2,160, 1922). Experiments were conducted to determine the permeability of silica glass, Pyrex glass and Jena combustion glass to air, hydrogen and helium. Silica glass is permeable to hydrogen at high temperatures. The permeability is proportional to the gas pressure and is an exponential function of the temp. Above 300° it becomes appreciable. Silica glass is similarly permeable to helium. At 500° this permeability is about 22 times that of hydrogen. Neither Pyrex nor Jena glass was found to be permeable to hydrogen, but the gas apparently reacts with the Pyrex, causing it to blacken. Pyrex is also permeable to helium.

THE MEDIÆVAL GLASS OF YORK MINSTER.—W. F. Norris (*J. Soc. Glass Tech.*, **6**, 160, 1922).

THE PRODUCTION OF COLOURLESS GLASS IN TANK FURNACES, WITH PARTICULAR REFERENCE TO THE USE OF SELENIUM. PART I.—A. Cousen and W. E. S. Turner (*J. Soc. Glass Tech.*, **6**, 168, 1922). A large number of meltings were carried out on a small scale to determine the relative effect of selenium and sodium selenite as decolorisers both in salt-cake batches and others. The meltings were mainly carried out at 1,380° but some also at 1,440°. The maximum percentage of iron oxide which it was found possible to decolorise by selenium or sodium selenite was 0·09. Very small quantities of salt-cake in the batch required an increased amount of selenium for decolorising purposes. There is evidence that selenium reacts with salt-cake at high temp. and is converted to some extent into sodium selenite. Sodium selenite is more effective than elementary selenium in

batches containing soda-ash only. On reheating, colour changes occur only in glasses which have been over-decolorised and which have a distinct selenium tint. The effect of reheating is to deepen the tint (between 525—550°). Further experiments are in progress.

A CRITICAL REVIEW OF THE PROVISIONAL SPECIFICATIONS FOR GLASS REFRACTORY MATERIALS.—W. J. Rees (*J. Soc. Glass Tech.*, **6**, 181, 1922).

COLUMNAR STRUCTURE IN SANDSTONE BLOCKS.—J. Currie (*J. Soc. Glass Tech.*, **6**, 156, 1922). Instructing examples of superinduced prismatic structure were observed in sandstone blocks used in the construction of a glass tank furnace which had been in operation for a number of years. Sandstone blocks formed the lowest course of the sides of the tank. The prismatic formation was identical with that which takes place in nature, particularly in the case of columnar basalt. The evidence goes to prove that the formation started at the point of contact with the glass, and that, as in Nature, columnar jointing is distinctly related to the planes of cooling. Reference is made to J. W. French's work (see TRANS., **21**, 81A, 1922). There are four photographic illustrations.

THE MELTING OF GLASS. PART II.—(*J. Soc. Glass Tech.*, **6**, 147, 1922). Continuation of a general discussion. The subjects discussed were: (1) the proportion of cullet to batch needed in the production of satisfactory glass; (2) the advantages and disadvantages attending the use of salt-cake as a constitutent of glass batches; (3) the time required for "standing-off"; (4) the effect of different methods of charging in batch on the homogeneity of the glass produced; (5) the equipment needed for the technical control of a window-glass tank furnace.

THE DISINTEGRATION OF SODA-LIME GLASSES IN WATER.—A. E. Williams (*J. Amer. Cer. Soc.*, **5**, 504, 1922). Soda-lime glasses were treated in water at temperatures below boiling point, at boiling point, and up to 25 lb. pressure in an autoclave. Nine photographic illustrations of the results show that glass disintegrates (cracks, spalls, and loses weight) when treated at any temp. The rate of disintegration depends upon the time, temp., composition, and heat treatment of the glass surface during forming, the latter factor apparently affecting considerably the spalling or chipping tendency. The relative endurance of glasses under service conditions may be studied by the methods applied, and standard methods of testing based upon them can be worked out. To be of good quality, glass should stand at least 6 hours in boiling water without apparent disintegration. Spalling always appeared on the exterior only of pressed or blown ware. Disintegration of glass is cumulative with the time of treatment, whether it be periodic or continuous. Treating glass in hot water with increasing pressure does not appear to give greatly increased disintegration as the temp. and pressure rise. The surfaces of blown or pressed articles are shown to be laminated rather than smooth and impervious.

THE BRITISH GLASS INDUSTRY; ITS DEVELOPMENT AND ITS OUTLOOK.—W. E. S. Turner (*J. Soc. Glass Tech.*, **6**, 108, 1922).

THE NEW PLANT OF THE UNITED STATES SHEET AND WINDOW GLASS COMPANY AT SHREVEPORT, LOUISIANA.—J. B. Krak (*Glass Ind.*, **3**, 171, 1922). A well-illustrated description.

GOLD LETTERING ON GLASS.—(*Diamant*, **44**, 663, 1922). Waterglass solution of 40 Bé is applied to the parts of the glass to be treated, and gold leaf is then pressed on in the required positions. The piece is warmed to 36°C. and partially dried, the design or lettering is sketched on in pencil, the superfluous gold removed, and the drying completed at a higher temperature.

GLASS FROM AN ALCHEMIST'S LABORATORY IN GLOUCESTER.—G. Embrey (*Proc. Cotteswold Naturalists' Field Club*, **21**, 43, 1922). The remains of a crude melting furnace were found during excavation work on the

site of the Grey Friars' Priory, at Gloucester in 1882. At a depth of 4 or 5 feet, a clay crucible (photographed) was discovered partly filled with green glass. The author analysed a portion of the glass which contained: 60% silica, 9·6% alumina, 3·8% lime, 3·0% iron oxide, 17·6% potash, 3·2% soda and 2·6% chromium oxide. The Grey Friars' Priory was dissolved *circa* 1536. The question as to where the raw materials were obtained is discussed, and it is concluded that the alchemist probably got his sand from Robins' Wood Hill and his wood ashes from the Forest of Dean. The chromium required in small quantity to produce the beautiful green colour probably came from specimens of old glass. Some interesting references to the Gloucester "Glass Houses" are given, taken from the Register of St. Nicholas Church (1694/5) and from the *Gloucester Journal* (1741 and 1744).

GAS PRODUCERS AND FURNACES IN THE GLASS INDUSTRY.—K. Schneider (*Glashütte*, **52**, 625, 1922). An illustrated account of the various types of producers and furnaces.

THE SCIENTIFIC DEVELOPMENT OF THE GERMAN GLASS INDUSTRY.—(*Verre*, **12**, 170, 1922).

AN IMPROVED TYPE OF GAS-PRODUCER FOR THE GLASS INDUSTRY.—H. Novotny (*Verre*, **2**, 177, 1922). A sketch if given of an improved type of Morgan generator, having air inlets at the centre and at the sides. The apparatus is capable of dealing with from 9,000 to 10,000 kgs. per day.

THE GLASS INDUSTRY OF IRELAND.—(*Verre*, **2**, 178, 1922).

LIME FOR GLASS MAKING.—R. R. Shively (*Glass Ind.*, **3**, 154, 1922). The advantages and disadvantages of the three kinds of lime as used in glass making—limestone, quicklime and hydrated lime—are discussed. Specifications which have proved satisfactory in many instances are also given.

A STUDY OF BROWN GLASS MILK BOTTLES.—A. W. Bitting (*Glass Ind.*, **3**, 157, 1922). Investigations at the Iowa Agricultural College showed that, on the whole, clear glass is more suitable than brown, or amber, glass for bottling milk, especially from a hygienic point of view.

THE SIMPLIFICATION AND STANDARDIZATION OF BOTTLES.—M. J. Owens (*Glass Ind.*, **3**, 164, 1922).

QUARTZ GLASS.—G. Flusin (*Verre*, **2**, 145, 1922). A comprehensive account of the properties, history and manufacture.

NOTES ON DIAGNOSING CAUSES OF CORDS IN GLASS.—F. Twyman (*J. Amer. Cer. Soc.*, **5**, 289, 1922). Much information may often be obtained very readily by noting the difference in refractivity, viscosity, and expansion coefficient between the cords and the mass of the glass. Methods are described for rapidly determining the relative values of these physical properties. This information, together with a knowledge of the batch ingredients and possible impurities may afford in certain cases a means of determining the cause of the cords.

THE GLASS INDUSTRY IN BELGIUM, 1921.—(*J. Soc. Chem. Ind.*, **41**, 353R, 1922). Statistics, taken from the U.S. Com. Rep., Apr. 17 and May 8, 1922.

CONVEYING GLASS COFFINS.—(*Eng. Ind. Man.*, **8**, 200, 1922). The Glass Casket Corporation, of Altona, Pa, are now casting glass coffins, weighing 255 lb. and measuring about 6 ft. 3 in. in length. The glass is approx. half an inch thick. The annealing lehr is 8 ft. wide and 84 ft. long, the annealing period being about 6 hours, 2 hours for soaking and 4 for cooling. The caskets are taken through the lehr by means of a conveyor formed of steel slats attached to two chains. A small electric motor drives the conveyor.

PATENTS.

GLASS BLOCKS.—F. L. Keppler (*Pat. J.*, 1,760, 1922). No. 184,655, July 6, 1921. Describes a special form of block suitable for pavements, skylights, etc.

BOTTLE-MAKING MACHINE.—S. C. Halse and T. Jones (*Pat. J.*, 1,760, 1922). No. 184,699, Aug. 23, 1921. Relates to machines in which a divided ring mould is employed. One half of the mould is fixed to a carrier plate, while the other half is carried by an arm pivoted to the carrier plate. The arm can be moved by a handle to separate the two halves.

DRAWING GLASS SHEETS.—J. W. Mellersh-Jackson (*Pat. J.*, 1,761, 1922). No. 184,989/90, July 28, 1921. Relates to means for drawing glass sheets and protecting the sheet during drawing.

DRAWING GLASS SHEETS AND CYLINDERS.—A. Braucart (*Pat. J.*, 1,763, 1922). No. 185,520, June 8, 1921. Sheets and cylinders are produced by drawing molten glass upwards as it tends to flow over the edge of a wall.

DRAWING GLASS SHEETS.—W. J. Mellersh-Jackson (*Pat. J.*, 1,764, 1922). No. 185,921. Those portions of the surface of the molten metal from which the edge of the sheet are drawn, are chilled and forced to flow upwards into the sheet.

ANNEALING.—Hilger Ltd. and F. Twyman (*Pat. J.*, 1,765, 1922). No. 186,160, June 21, 1921. A rod of the substance (glass, porcelain, and some metals) to be annealed is fixed by a screw in a tube and is bent down against a stop by a bell-crank lever operated by wires attached to another lever. The apparatus is placed in the annealing oven and the lever is released periodically to ascertain when the rod ceases to return to its original form. The degree of permanent distortion is indicated on a scale and is a measure of the degree of annealing.

DRAWING SHEET GLASS.—W. J. Mellersh-Jackson (*Pat. J.*, 1,766, 1922). No. 186,479, July 28, 1921. Supplementary to Specifications 15134/15 and 114,977.

GLASS FURNACES.—R. Haddan (*Pat. J.*, 1,766, 1922). No. 186,547, Dec. 24, 1921. Describes a special construction of a tank furnace for cooling purposes.

TRANSFERRING DEVICE FOR GLASS CYLINDERS.—Empire Machine Co. (*Pat. J.*, 1,766, 1922). No. 186,569, Nov. 2, 1921. Description of a hand truck fitted with a turntable on which are mounted carved supports for the cylinders.

VI.—CEMENT, CONCRETE, MORTARS, ETC.

STANDARD TESTS FOR TRASS.—(*Tonind. Ztg.*, **46**, 1,088, 1922). The standards adopted by the German Society for Testing Technical Materials are outlined.

CEMENT SLABS.—(*Cer.*, **25**, 311, 1922). Extract from the *Bulletin officiel de la Direction des Recherches scientifiques et industrielles et des Inventions*, No. 34, 509, 1922. An account is given of the manufacture, uses and advantages of cement slabs made on the Broutta system. These consist of an agglomeration of cement, clinker and sand, and measure 50 cm. square, 16 mm. thick and weigh about 5 kg. each.

HOLLOW CONCRETE POLES.—E. Haimovici (*Tonind. Ztg.*, **46**, 1,113, 1922). An account is given of the manufacture of hollow concrete poles, made by the centrifugal process, for supporting electric lighting, power, or high tension cables. Four illustrations are given, including one of masts approximately 60 ft. in length.

THE UTILIZATION OF WASTE HEAT FROM ROTARY FURNACES.—J. Bied (*Chim. Ind.*, **8**, 528, 1922). The vertical cement furnace is almost perfect from the point of view of heat utilization, but the horizontal rotary type is less efficient. It is shown by calculation that about 600,000 cal. per ton of cement are lost by the chimney in the rotary kiln. Details of some existing installations are given.

CONVEYING IN A CEMENT PLANT.—(*Eng. Ind. Man.*, **8**, 199, 1922). A brief account is given of the plant of the Bessemer Limestone and Cement Co. Ltd., Bessemer, Pa, at which all material is moved wherever possible by means of belt conveyors. Ball-bearing rollers are used throughout, and all the belts are 20 in. wide.

CONCRETE ROAD CONSTRUCTION IN ILLINOIS.—(*Cement Eng. News*, **34**, No. 8, 21, 1922).

QUALITY CONTROL IN CEMENT MANUFACTURE.—R. K. Meade (*Cement Eng. News*, **34**, No. 8, 27, 1922). The problem of making cement of a uniformly high quality is mainly a question of absolute control of the chemical composition of the mixture fed to the kilns. This factor is discussed in a practical manner.

RESEARCHES ON LIME.—F. C. Mathers (*Rock Prod.*, **25**, No. 16, 33, 1922). A summary of the results of research work carried out at Indiana University.

HIGH-STRENGTH CEMENTS.—J. Hendrickx (*Chim. Ind.*, **8**, 297, 1922). Attention is mainly directed to special Portland cements. The conclusions are : (1) care must be taken to ensure regularity of chem. comp. of the raw mixture ; (2) the physical homogeneity of the raw mixture is important ; (3) the presence of rare materials in small amounts appears to have an important bearing on the qualities of certain cements ; (4) firing and cooling should be so conducted as to produce crystals as large as possible ; (5) grinding should be as fine as possible, special attention being paid to the "modulus of fineness," *i.e.*, the relationship between sp. gr. and the weight of an untamped litre.

ALUMINA CEMENT—ITS DEVELOPMENT, USE AND MANUFACTURE.—H. S. Spackman (*Rock Prod.*, **25**, No. 16, 30, 1922 ; *Cement Eng. News*, **34**, No. 10, 18, 1922). A description of a high-strength, quick-setting cement produced commercially in France. Investigations by three independent workers, including the writer, demonstrated that slow-setting, rapid-hardening cements can be produced by the calcination of mixtures of alumina and lime in which the ratio of the available lime to the alumina does not exceed the monocalcic proportion. A French variety, known as "ciment électrique," contains fixed quantities of silica and iron oxide and is made by grinding a product obtained by fusing a predetermined mixture of silica, alumina, iron and lime in an electric furnace. The cement is slow-setting like ordinary Portland cement, but it hardens rapidly and gives high strengths at early periods and is unaffected by sea water, etc. At the end of 24 hours its strength equals that of Portland cement after one month. Its greater strength is shown by the fact that, in making calculations for structures, the compression members may be figured at 2,000 lb. per sq. in., instead of at 700 lb. generally used for Portland cement. Some instances of its structural applications in France are given.

THE APPLICATION OF THE FUNDAMENTAL KNOWLEDGE OF PORTLAND CEMENT TO ITS MANUFACTURE AND USE.—P. H. Bates (*Quarry*, **27**, 305, 1922). An abstract of a paper presented to the Franklin Institute. A historical résumé is followed by an account of the work done by the Bureau of Standards at its experimental cement plant at Pittsburgh.

A STUDY OF CONDITIONS CAUSING DISINTEGRATION OF CEMENT UNDER THE "ACCELERATED" TEST.—A. G. Fleming (*J. Soc. Chem. Ind.*, **41**, 300T, 1922). An abstract of a paper read before the Montreal Section of the Soc.

A NEW CEMENT PLANT IN MEXICO.—H. E. Leach (*Rock Prod.*, **25**, No. 18, 24, 1922). A well-illustrated description of the new plant of the Cia. de Cemento Portland, Monterrey, S.A.

THE RESISTANCE TO FIRE OF CONCRETE AND REINFORCED CONCRETE.—F. C. Lea and R. E. Stradling (*J. Soc. Chem. Ind.*, **41**, 395R, 1922). An abstract of paper read before Section G. (Engineering) of the British Association. The problem was considered under two headings: (1) the possibility of making a concrete which should retain its strength after exposure to high temp., and (2) the possibility of preventing steel from reaching such a temp. that its strength is reduced to, or below, that required to carry the loads.

PATENTS.

MOULDING REINFORCED CONCRETE.—W. Sykes (*Pat. J.*, 1,760, 1922). No. 184,555, May 10, 1921. An extrusion machine for moulding long reinforced plastic articles is so arranged, that extension of the material against a fixed support automatically retracts the machine on ball bearings.

SLABS, TILES, ETC.—Durato Asbestos Flooring Co. Ltd., and A. Z. Neweth (*Pat. J.*, 1,761, 1922). No. 184,910, May 31, 1921. Sawdust is soaked in 10° Bé magnesium chloride solution until thoroughly saturated and then mixed with calcined magnesite, (1 to 3 or 4 by volume) soapstone (one-tenth of combined sawdust and magnesite), and a further quantity of 15° Bé mag. chloride solution, and moulded into slabs, etc.

CONCRETE MIXING MACHINES.—G. Jaeger (*Pat. J.*, 1,762, 1922). No. 185,317, Aug. 22, 1921. Relates to machines with a single opening for fuel and discharge and a bucket for introducing the materials.

MOULDING CONCRETE PIPES, ETC.—A. N. Macnicol (*Pat. J.*, 1,764, 1922). No. 186,048, Aug. 22, 1922. Means are provided for moulding pipes, etc., centrifugally and also for reinforcing and connecting.

BUILDING BLOCKS.—P. J. White (*Pat. J.*, 1,765, 1922). No. 186,165, June 24, 1921. Relates to blocks consisting of two hollow bricks joined together, one overlapping the other.

CEMENTS.—G. Schloesser (*Pat. J.*, 1,769, 1922). No. 187,362, Aug. 8, 1921. The heat generated by the combustion of town refuse is utilized to burn calcium carbonate, which is added to the refuse to form a cement or mortar.

FACING SLABS, TILES, ETC.—M. Auspach (*Pat. J.*, 1,769, 1922). No. 187,499, Dec. 7, 1921. Slabs, panes, glass tiles, etc., are prepared for securing to walls with mortar or cement, by coating with a mixture of earth or ochre (14 volumes), linseed oil (3 vols.), turpentine (2 vols.), resinous varnish (1½ vols.), and a siccatine (4 vols.) and baking at 100°C. for about 10 minutes.

CEMENT MANUFACTURE.—Gebr. Bühler (*Pat. J.*, 1,769, 1922). No. 187,579, July 21, 1922. Part of the slurry is burnt in rotary kilns, the waste gases from which are used to dry another portion of slurry, enabling it to be burnt in shaft kilns.

CONCRETES.—A. Kleinlogel (*Pat. J.*, 1,769, 1922). No. 187,582, Aug. 3, 1922. In concretes consisting of cement and finely-divided hard substances (iron, steel, carborundum, etc.), the ratio of hard substance to cement is given by the formula : $(100 \pm 177{\cdot}8\,x)/(54 \pm 76{\cdot}2\,x)$ where x is the difference in inches between the diam. of the grains of hard substance and 0·03937 inch, the upper sizes referring to grains of larger soize than 0·03937 in. and the lower to smaller sizes.

COATING COMPOSITIONS.—J. Davies and W. H. Miles (*Pat. J.*, 1,765, 1922). No. 186,231, Aug. 24, 1921. A preparation for treating metallic surfaces before magnesium oxychloride cements are applied thereto, consists of calcium fluoride, calcium carbonate, and a solution of sodium or potassium

silicate with or without powdered clay (pipe clay or china clay). The clay may be replaced by calcined magnesite. Suitable proportions are 10 lb. each of calcium carbonate, calcium fluoride and clay, and 18 lb. of sod. silicate solution of 33° Bé.

REINFORCED-CONCRETE RAILWAY SLEEPERS.—R. Addison and C. A. Guttridge (*Pat. J.*, 1,766, 1922). No. 186,356, Oct. 15, 1921.

MOULDING CONCRETE.—S. Wright (*Pat. J.*, 1,766, 1922). No. 186,431, Mar. 22, 1922. Description of a machine.

MOULDING CONCRETE PIPES.—R. Last (*Pat. J.*, 1,767, 1922). No. 186,660, June 3, 1921. Relates to machines for moulding oval concrete pipes.

MOULDING CONCRETE BLOCKS.—H. E. Williams (*Pat. J.*, 1,768, 1922). No. 187,103, Sept. 13, 1921. Description of a machine.

VIII.—HISTORICAL, EDUCATIONAL, INSTITUTIONS, HYGIENE, ETC.

LINTHORPE POTTERY.—(*Pot. Gaz.*, **47**, 1,387, 1922). An account of the characteristics, history and development of Linthorpe Art Pottery.

ORIGIN OF BRICK.—(*Claywr.*, **78**, 229, 1922). An account is given of the primitive methods used by the Pueblo Indians of New Mexico.

THE FUNDAMENTALS OF THE REFRACTORY INDUSTRY.—Hirsc (*Tonind. Ztg.*, **46**, 1,037, 1922). An abstract of a lecture at the Brickmakers' School, Frankfort-on-Oder, dealing with the fundamental principles.

THE IMPORTANCE OF REFRACTORIES TO THE GERMAN INDUSTRIAL COMMUNITY.—K. Jacob (*Tonind. Ztg.*, **46**, 887, 1922). This article was awarded second prize in a competition inaugurated by the German Refractories Manufacturers' Association for propaganda purposes. It deals at some length, in a popular, non-technical form, with the Refractories Industry in general, and its relation to other branches of industry, viz.: metallurgy, heavy chemicals, pottery, cement and lime, glass, laboratory apparatus, gasworks, boiler fires, generators, etc.

THE ORIGIN OF THE WORD "SCHAMOTTE."—(*Tonind. Ztg.*, **46**, 1,175, 1922). The word first made its appearance in a book by Fr. J. Weber: "Die Cunst das echte Porzellain zu machen," (Hannover, 1798), in which ground saggar body is referred to as "Skarmotti." The bulk of the evidence points to the word being of German origin.

NOTED BRICK BUILDINGS OF LEIPZIG.—H. Ermisch (*Tonind. Ztg.*, **46**, 847, 1922).

THE DEVELOPMENT OF ANCIENT CERAMICS UP TO HELLENISM.—Badermann (*Glas-Ind.*, **33**, 173, 1922).

POTTERY MANUFACTURE IN INDIA.—(*Pot. Gaz.*, **47**, 1,373, 1922).

LEAD POISONING IN THE U.S. POTTERY INDUSTRY.—(*Pot. Gaz.*, **47**, 1,376, 1922). A Report to the U.S. Public Health Service on investigations begun in 1919. The chief portals of entrance by which lead enters the body are the stomach and the lungs. The largest percentage of poisoning among men was found among the dippers. The usual precautionary measures are recommended.

SOME UNIQUE BASALTE VASES.—(*Pot. Gaz.*, **47**, 1,382, 1922). An account, with illustration, of some Wedgwood vases made specially for Winnington Hall, Cheshire.

SWISS POTTERY.—(*Pot. Gaz.*, **47**, 1,386, 1922). A short, illustrated account of both the domestic and the factory industry in Switzerland.

Abstracts.

I.—RAW MATERIALS: GENERAL.

RAW MATERIALS: OCCURRENCE, PREPARATION, ETC.

KAOLIN DEPOSITS IN BRITISH COLUMBIA.—(*Pot. Gaz.*, **47**, 1702, 1922). A large deposit of very pure kaolin has been discovered near Williams Lake, B.C. Hard, white, non-absorbent tiles, which take a good glaze, were prepared by the Department of Mines at Ottawa. The establishment of a fine pottery and tile industry is proposed.

DISCOVERY OF KAOLIN, ETC., IN RUSSIA.—(*Pot. Gaz.*, **47**, 1703, 1922). Extensive deposits of kaolin, graphite and manganese have been discovered in the Odessa province and exploitation has begun.

GYPSUM IN IRELAND.—(*Bull. Imp. Inst.*, **20**, 243, 1922). A large deposit of gypsum has been found near Carrickmacross, Co., Monaghan, and at Lishaboe, Co. Meath, a body of gypsum estimated at a million tons has been located while boring for coal. A factory capable of producing 25 tons of plaster of Paris per day is being erected.

KAOLIN DEPOSITS IN THE DOBRUDJA.—(*J. Soc. Chem. Ind.*, **41**, 571R, 1922). Large deposits have recently been discovered between Balcic and Cavarna. The Roumanian Government has decided to erect a large porcelain factory at Balcic and to import skilled labour from Czecho-Slovakia and Austria.

CHINA CLAY IN QUEBEC.—(*Can. Chem. Met.*, **6**, 245, 1922). The Canadian China Clay Co. is now in a position to produce a good grade on an economical basis. The deposits being operated are at Huberdeau, Quebec. The kaolin zone is about 1,000 ft. wide and 7,000 ft. long. Much of the clay is stained with iron, but makes a good fireclay. Regular mining methods are used.

THE PURIFICATION OF CLAY.—(*Chem. Age*, **8**, 57, 1923). A short, general discussion of the subject.

HYDRATED SILICA.—G. Durocher (*Ind. Chim.*, **9**, 533, 1922). The uses of the material in the chemical industry are outlined.

CARRARA MARBLES.—A. Nicoli (*Corr. Cer.*, **3**, 213, 1922). Mainly statistics.

LIME FOR LIME-SAND BRICKS.—(*Brick Pot. Tr. J.*, **31**, 9, 1923). The best lime is one which slakes readily and completely; it should be fat, white in appearance, and contain 95% or more of calcium oxide. The chem. analyses of 9 limes are given and their properties discussed.

USE OF REFRACTORY SANDS.—(*Brit. Claywr.*, **31**, 333, 1923). An illustrated description of the plant and methods of the Ottawa Silica Co., taken from G. H. Boswell's book: "A Comparison of British and American Foundry Practice."

ELECTRIC-FURNACE PURIFICATION OF ZIRKITE.—J. G. Thompson (*Trans. Amer. Electrochem. Soc.*, **40**, 445, 1922). Details are given of an investigation undertaken with the object of ascertaining to what extent zirkite (impure zirconium oxide) might be freed from impurities by direct heating in an electric furnace. It was found that in the resistance type of furnace, the rate of power input was insufficient to attain the high temperature desired (over 2,220°C.). In the arc type, 90–95 percent of the silicon was removed from the ore by heating a mixture of ore and carbon to a temperature above 2,220°. The best results were obtained by adding only that amount of carbon which was required approximately to transform the silicon into the carbide. With excess carbon, a double carbide of silicon and zirconium

probably forms, which requires further study. It is suggested that zirconia sufficiently pure for refractory purposes, might be obtained from zirkite ore by removing the silicon in an electric furnace and following this by treatment with chlorine or phosgene to remove the iron. With regard to the refractory properties of zirconium carbide and the factors limiting its use, it is stated that, with an excess of carbon present, it is impossible to melt the product even under the direct action of a 40–50 kilowatt arc. The partially purified carbide has a higher melting point than the oxide product with the same relative composition. In order to use the carbide as a refractory, however, it would be necessary to protect it from oxidation. The black carbides all burn readily in air to form light fluffy oxides. Heating to dull redness is sufficient to start the oxidation, which then proceeds slowly but persistently.

REPORT ON MANCHURIAN MAGNESITE.—Kosuke Hirano (*J. Jap. Cer. Ass.*, 361, 414, 1922). The colour, appearance, sp. gr., chemical composition and burning properties of 102 specimens of magnesite, which were all collected from mine-lots possessed by the South Manchurian R.R. Co., except the Mt. Kamba and the Mt. Gyushin magnesites discussed by the author in April, 1919, are described in detail. Sp. gr. varies from 2·76 to 3·01. They have the following composition: 0·20–30·28% silica, 0–1·80% alumina, 0·18–4·37% ferric oxide, 0–24·12% lime, 16·32–47·02% magnesia and 36·20–51·78% loss on ignition. S. KONDO.

PATENTS.

TREATMENT OF CLAY.—W. Feldenheimer and W. W. Plowman (*Pat. J.*, 1,767, 1922). No. 186,855, Nov. 21, 1921. Addition to Spec., 184,271 (*v.* p. 2). A dilute aqueous solution containing the pyro-phosphate of an alkali base, *e.g.*, sodium pyro-phosphate, may be used as a deflocculating agent. The clay may be removed subsequently from its suspension by the process of deflocculation described in Spec. 121,191 or otherwise.

TREATING SILICATES.—H. Plauson (*Pat. J.*, 1,772, 1922). No. 188,454, Sept. 16, 1921. 100 parts of ground felspar are heated with about 200 parts calcium chloride at a temp. of 650°C. and the resultant mass is extracted with water. Hydrated calcium chloride may be used if heating is effected under pressure.

TITANIUM DIOXIDE; VANADIUM COMPOUNDS.—E. E. Dutt (*Pat. J.*, 1,775, 1923). No. 189,700, Feb. 10, 1922. After washing, the residues from the treatment of certain bauxites by the Bayer process are disolved in HCl to yield a solution containing about 100 grm. titanium chloride per litre. Excess acid is then neutralised, the iron is reduced, and alkali acetate added to the extent of $\frac{1}{10}$ of the titanium chloride present. The soln. is boiled to precipitate titanium dioxide and almost completely neutralised. The filtrate is treated with barium salts to precipitate barium vanadate.

PHYSICAL AND CHEMICAL PROPERTIES, TESTING, ETC.

THE GRADING OF POWDERS BY ELUTRIATION.—T. M. Lowry and L. P. McHatton (*Trans. Faraday Soc.*, **18**, 23, 1922). Experiments were made to determine the diameter of the particles of barytes and of quartz which are just lifted by a vertical flow of water at a velocity of 4, 5, 6, 7 and 8 mm. per second. The grading was found to be much more exact in a tube having an internal diam. of 27 mm. than in one with an internal diam. of 13 mm. The critical diam. of the particles is also about 5% greater in the narrow than in the wide tube. The critical diam. decreases with rising temp., the temperature-coefficient being 0·4% per degree. The relationship between critical diam. and velocity is given by the formula: $\log d = 2{\cdot}67 + kv$, where k is a constant depending on the diameter of the tube and the temp. of the water. Under identical conditions the diameters are 1·42 times as great for quartz as for barytes, the sectional areas of the particles being therefore in the ratio 2 : 1. The latter ratio is practically identical with

that of the gravitational forces on the particles. The lifting power of the water is therefore proportional to the area of the particle.

THE PLAGIOCLASE FELSPARS AS A CASE OF ATOMIC ISOMORPHISM.—E. T. Wherry (*Amer. Mineralogist*, **7**, 113, 1922).

CLAY; WITH SPECIAL REFERENCE TO ITS PHYSICAL CHARACTERISTICS AND THE VARIOUS METHODS OF MANUFACTURE SUITED TO THEM.—A. E. Brown (*Brit. Claywr.* **31**, 278, 1922). The subject is treated in general terms under the following subheadings: History of bricks; geology (very brief); types of clay; chemistry; physical properties; uses of clay; electric osmosis; treatment of clays in manufacture; drying; kilns and burning of clay goods.

NOTES ON THE COMPOSITION OF TALC.—W. F. Foshay and E. T. Wherry (*Amer. Min.*, **7**, 167, 1922).

PHYSICAL PROPERTIES OF CLAY.—(*Nature*, **111**, 202, 1923). A short review of four papers, presented by A. S. E. Ackermann to the Society of Engineers, in which experiments directed towards determining the bearing power of clays and soils are described.

CAPILLARY TESTS WITH KAOLIN.—R. E. Liesegang and M. Watanabe (*Sprech.*, **56**, 56, 1923).

THE EFFECT OF SMALL ADDITIONS OF ELECTROLYTES ON THE STABILITY OF CLAY SUSPENSIONS, AND THE USE THEREOF TO PURIFY CLAYS.—H. Kohl (*Ber. D. K. Ges.*, **3**, 64, 1922). The writer sets out to throw light, by means of experimental data, on the question as to whether, in the electro-osmosis process, the actual purification of the clay takes place during the preliminary treatment (with electrolytes, etc.) of the clay, or in the osmosis machine itself. The theory of the manner in which electrolytes effect clay suspensions is discussed, and there are numerous references to the work of previous investigators. On the basis of actual experiments, it is concluded that, contrary to the views expressed by F. Singer and others, the impurities present in ordinary clays (quartz, felspar, mica, pyrites, etc.) cannot be considered as containing an electric charge opposite to that of kaolin; on the contrary, they usually show quite similar behaviour electrically. Finely divided quartz was deposited like kaolin in weak alkali concentrations, and under electric treatment collected at the anode. The same behaviour was observed with felspar and mica, but the latter was coagulated by still smaller quantities of alkali. Similarly, the iron compounds, when in finely-divided condition like the clay, could only be separated to a slight extent. Dilute H_2SO_4 caused rapid deflocculation in every case. If these substances are present in coarser condition, they settle under the influence of gravity, and this separation can be aided considerably if, by the addition of suitable electrolytes, the stability of the clay suspension can be increased, the coagulated particles being at the same time disrupted, thus allowing any enclosed impurities to settle. It is assumed, therefore, that this part of the electro-osmosis process is responsible for the purification; further separation appears to be impossible by subsequent electrical treatment. The removal of superfluous water can be effected either in the filter-press or in the osmose machine without affecting the purity of the final product.

THE SEPARATION OF THE FINER CONSTITUENTS OF SEDIMENTARY ROCKS.—P. G. H. Boswell (*Trans. Faraday Soc.*, **18**, 34, 1922). A theoretical discussion of the fundamentals is followed by a description of the procedure in elutriation. Some notes are added on the limits of accuracy and possible experimental difficulties. The writer points out that a method of representation of the results of mechanical analyses should be agreed upon.

MICA CHINA CLAY.—(*China Rev.*, **5**, 146, 1922). A typical sample of mica china clay contains 2·10% potash. This gives the clay its fertilizing value. It is also used for most of those purposes for which china clay is em-

ployed, but confined to the cheaper manufactures, *e.g.*, cheap paper fillers, cheap pottery, etc.

THE EFFECT OF DISSOLVED SUBSTANCES ON DEPOSIT OF CLAY BY CATAPHORESIS.—R. D. Kleeman (*Phys. Rev.*, **20,** 272, 1922). The addition of 0·1 to 0·3% of one of a number of substances, *e.g.*, Na_2SiO_3, Na_2SO_4, Na_3PO_4, Na_2HPO_4, hydrogen tartrate, Na tartrate, NaOH and KOH, gave a deposit which, though not quite dry, was solid and not semi-liquid. Compactness is not dependent on the current density. With increase in the amount of substance added, the compactness increases at a diminishing rate until a limiting value is reached. The fluidity of the clay slip is markedly increased. Although the result of adding the substance is first to precipitate some of the particles, when more solid material is added the precipitate is redissolved, so that, for the same fluidity, the proportion of solid dissolved is much greater with the added subject than without. A theoretical explanation is discussed at some length.

II.—MANUFACTURING PROCESSES :

GENERAL.

THE MANUFACTURE OF FIRE-PROOF KITCHEN WARE.—F. Bigot (*Corr. Cer.*, **3,** 206, 1922).

SLAG BRICKS FOR BUILDING PURPOSES.—(*Allg. Tonind. Ztg.*, **42,** No. 3, 1, 1923). Slag from gas-works, etc., is now used extensively in Germany for brick-making for municipal building schemes. The sulphur content of the slag must not be high ; if necessary, the slag must be allowed to stand in the open for a sufficient length of time. At the Berlin gas-works the slag is screened to a grain size of 12 mm. and mixed in the proportion of 1 : 10, with cement as a binder. The mass is then moistened, thoroughly mixed, and passed to the Nestor brick-making machine. This machine makes six bricks simultaneously and is capable of turning out 500 per hour on an average. The bricks are stored on boards in the open.

THE MANUFACTURE AND USES OF "HOURDIS."—(*Allg. Tonind. Ztg.*, **42,** No. 11, 4, 1923). Hourdis are large, hollow bricks of burned clay measuring 50 to $100 \times 20 \times 7$ cm. They were first produced in Switzerland, and have proved particularly useful in ceiling and roof construction. They are comparatively light, and damp proof. The clay used in making "hourdis" must be fairly pure and highly plastic ; powdered brick grog must be added to counteract shrinkage.

SOME CHARACTERISTICS OF THE MANUFACTURE OF SILICA BRICKS IN DIFFERENT COUNTRIES.—(*Rev. Mat. Constr. Trav. Pub.*, No. 157, 151B, 1922). The different methods of manufacture in England, U.S.A., Italy, Germany and France are briefly described.

MODERN CHEMICAL STONEWARE.—P. C. Kingbury (*Chem. Tr. J.*, **72,** 35, 1923). The development of the American industry, which is centred in New Jersey, is outlined. The nature, and the physical and chemical properties of the ware, and also the method of manufacturing it, are discussed. The original paper appeared in *Chemical and Metallurgical Engineering.*

THE LATEST DEVELOPMENTS IN GERMAN FINE CERAMICS, WITH SPECIAL REFERENCE TO THE MANUFACTURE OF PORCELAIN AND STONEWARE EMERGENCY COINAGE.—W. Funk (*Zeits. angew. Chem.*, **35,** 81, 1922). The first part deals with modern conditions in the German fine ceramic industry in general. The second gives an account of Böttger stoneware, and more particularly of the manufacture of emergency ceramic coinage at the State Porcelain Works at Meissen (*c.f. Trans.*, **20,** 8 A, 1921). A short historical note is followed by a discussion of the manufacturing process. Special importance attaches to the burning process, since in firing the stoneware body, which is rich in iron and lime, both a reducing fire and overheating must be avoided.

A MOVEMENT TO IMPROVE REFRACTORIES.—(*Brick*, **61**, 867, 1922). An industrial survey is to be conducted by the Refractories Manufacturers' Association in cooperation with committees representing users of refractory bricks and with individuals, firms and corporations to whom this material is an industrial necessity. The information is to be gathered by means of a rather elaborate questionnaire, which will cover temperature and combustion conditions in the typical furnaces, abrasion, slag action, the presence or absence of uncommon furnace gases, spalling conditions, loads, insulation, character of draught, etc.

Patents.

MANUFACTURING SPARKING-PLUG AND OTHER REFRACTORY PORCELAINS.—Shintaro Niimura (*Jap. Pat.* No. 41,540, Jan. 27, 1922). Sparking-plugs, porcelain crucibles and evaporating dishes are formed by casting slips which have previously been kept at reduced pressure by means of a vacuum pump to drive off the air or other gases contained in them. The slip may, at the same time, be heated or boiled, with constant stirring, or not. S. Kondo.

MANUFACTURING HEAT-INSULATING WARES.—Shinsaku Nagasaki (*Jap. Pat.* No. 41,666, Feb. 6, 1922). Stoves, small portable furnaces and similar vessels are formed with a stiff-plastic body, which has been prepared by mixing suitable amounts of clay and slaked lime with powdered or finely-ground coal-ashes. They are fired in a Japanese roofing-tile kiln. S. Kondo.

METALLIC COATINGS ON POTTERY.—Metallisator Ges. (*Pat. J.*, 1,774, 1923). No. 189,085, May 24, 1922. Ceramic cooking vessels are coated with aluminium or iron. The vessels are heated to 300–400°C. and the metal is applied by any of the known metal dusting processes.

CRUCIBLES, RETORTS, ETC.—Ferolite Ltd. and H. B. Clapp (*Pat. J.*, 1,775, 1923). No. 189,692. Feb. 7, 1922. Vessels for high temperature work are moulded from a mixture of chromite and ferro-silicon with a binding agent such as sodium silicate solution.

DOLOMITE BRICKS.—C. A. Longbottom, F. L. Duffield and W. J. Rees (*Pat. J.*, 1,780, 1923), No. 191,412, July 4, 1921. Refractory products composed of dolomite are sealed against hydration after firing by immersion in molten wax, tallow, dehydrated oils or fats, or similar substances. From 2–10% of iron oxide and 2–15% of clay, or 2–15% of each of slag and clay may be added to the dolomite. The mixture is moulded into bricks and shrunk by heating to about 1,500°.

PROCESS OF MANUFACTURING ROUGH-SURFACED ARCHITECTURAL POTTERY.—Ichiro Yokoi (*Jap. Pat.* No. 43,328, Aug. 23, 1922). Green bodies made of felspar, granite and bog iron ore are put in a saggar, leaving small spaces between them. The saggar is then filled with powdered calcined quartz. By firing it to a temp. a little below the melting point of the body, mottle wares with a rough surface are obtained. S. Kondo.

COMPOUNDING AND PREPARATION OF BODIES, ETC.

CRACKS IN BRICKS DUE TO FRICTION HEAT IN THE PRESS.—(*Allg. Tonind Ztg.*, **41**, No. 46, 2, 1922). Cracks in bricks (not "dogs teeth") are often caused by the clay becoming warm in the press, thus losing its plasticity to some extent. The trouble is more often due to unsuitable preparation of the clay, than to faulty construction of the press, particularly if the body is too stiff. To restore plasticity in such cases, steam may be introduced into the press. But it is important to work with the body in a soft and plastic form. Soaking the clay in water is recommended, even if only for half a day.

PRACTICAL HINTS ON THE MANUFACTURE OF EARTHENWARE.—G. Steinbrecht (*Ker. Rund.*, **30**, 465, 1922).

FINE STONEWARE.—W. Pukall (*Ber. D. K. Ges.*, **3**, 280, 1922). The author set himself the task of reviving the old Bunzlau brown ware industry, and with this object in view, developed and improved the methods of preparation at the Bunzlau Pottery School. The new body mixture recommended by the School contained approximately 50 parts clay substance, 38 quartz, and 12 felspar. The Bunzlau clay is sandy, contains little iron, and fuses at cone 31, and any similar clay can be employed for the purpose. A body midway between earthenware and porcelain would contain 50 parts clay substance, 35 quartz and 15 felspar, so that the Bunzlau body may be placed between this and the earthenware body. In the writer's opinion, it is very similar to the east-asiatic "porcelain" (so-called).

SHAPING, MOULDING, DRYING, ETC.

FLASHED SURFACES ON CAST WARE.—K. F. Pfefferkorn (*Sprech.*, **55**, 441, 1922). The almost complete lack of information dealing with "flashing," (the vitreous patches found on ware cast with alkaline slip) induced the author to undertake an experimental study of the problem. In his experimental work he commenced with the simplest possible conditions. The slip used consisted of one washed clay, the composition of which was determined by analysis. Distilled water was employed to make the slip, and no alkalies of any description were added. The pouring was carried out by allowing the moderately thin slip to flow through an aperture in the base of a container, the stream, with a diameter of 4 to 5 mm., falling on to a flat horizontal plaster surface. The plaster mould used was rectangular in shape (10 cm. square), with an internal depth of 1 cm. The volume of the mould could be increased by placing a rectangular plaster crown in position on the mould proper. Thus, after casting, a square plate of clay was obtained, which could easily be taken from the mould after first removing the crown. The "pourer" consisted simply of an inverted metal container with a well-fitting perforated cork. A glass tube, with stop-cock, was fixed into the perforation. Casting trials were made with five different clays in turn. In order to ensure a certain uniformity in the materials used in all the trials, the raw clay was tested in the following manner : a moderate quantity of the clay was moistened with distilled water to a thin consistency and passed through a copper-bronze wire sieve containing 200 meshes per sq. cm. (about 35 per linear inch). This eliminated all coarse sand, stone, pieces of wood, etc., only the fine sand, clay substance and felspar passing through. The latter mixture was then thoroughly dried and well ground. Two kilograms of the powdered material were then mixed with 5 litres of distilled water, to a moderately thin slip, with which the trials were carried out. A new mould was used for each trial. In order to determine the composition of the clays, Seger's method of rational analysis was chosen in preference to the purely chemical method. The accuracy of the results was tested by an independent determination of the total SiO_2 in the washed clays.

The analyses of the five clays are given. They had the following characteristics : No. I.—A very fat earthenware clay from Liboritz (Czecho-Slovakia) ; No. II.—A highly-plastic, fat, white-firing earthenware clay (Meissen) ; No. III.—A fat, white-firing clay (Meissen) ; No. IV.—A yellow-firing earthenware clay, containing mica, from Eger, Czecho-Slovakia; No. V.—a china clay from Pilsen, Czecho-Slovakia.

Clay I. is exceptionally fat, whilst clays II. and III., though highly plastic, are not so fat. This difference is still more pronounced in clay IV., which, in washed condition, contains only traces of felspar but much mica. It is a very fat clay.

In carrying out the casting tests, plates were made with each of the clays, the falling-height of the slip being varied. The moulds were dried for a considerable period at 110°C. and, when cold, were filled completely with slip up to the top rim of the crown. They were then allowed to stand until the plate had reached a "leather-hard" condition, after which they were removed

from the mould, placed with the lower surface on a clean sheet of plaster and covered with a second such sheet to prevent warping. By warming the plaster sheet to 110°C. in a drying chamber, the plates became thoroughly dry. They were then placed between two unglazed wall tiles and fired in a large biscuit oven. In glazing, the surface under observation, or "face," was held downwards, and the plate was allowed to remain in the glaze no longer than one second. In the glost oven, it was placed horizontally, on a triangular stilt, with the face upwards.

Casting Tests with Clay I. Some highly interesting facts were brought out even by the preliminary trials. A dark coloured ring appeared round the point where the slip struck the mould when the plate was in a raw, leather-hard condition. The slip of clay I. was almost black in colour, owing to its high content of carbonaceous and humus matter. Shortly after casting, the colour became lighter and changed to dark brown in the leather-hard state. When completely dried, the plate was grey in colour. The dark ring was then brown, owing to the fact that the material at that point still contained moisture. In the biscuit condition nothing was discernible, but after the glost fire, the following remarkable observations were made : in the centre of the plate, exactly where the stream of slip struck the mould, there was a circular patch, which had quite a normal glaze like the remainder of the surface. Encircling this there was a ring which was rough to the touch and had an extremely matt surface. The centre patch was well defined, whilst the ring merged gradually into the normal glaze surface. The size of the annular patch, or outer ring, is dependent upon the falling height of the slip the greater the height, the wider the ring, whilst the diameter of the central patch remains practically constant, and varies only with the diameter of the falling column of slip. These remarkable observations were confirmed on a large number of plates.

Casting Tests with Clay II. The dried plates showed the typical dark ring much less distinctly than those made of clay I. In some plates the ring disappeared entirely, but in others, it was just perceptible. The behaviour in the biscuit fire was still more remarkable. Although properly weighted, the plates warped considerably, and the "face" was covered with cracks running in all directions. After the glost fire, the glaze scaled off the whole of the face surface, yet adhered firmly to the under surface. No rough ring was perceptible, as with the glazed plates of clay I. The explanation of this remarkable behaviour was that, in casting with clay II., which contained much fine sand, the latter settled considerably in the container, so that the first material to reach the moulds was one containing much more fine sand than was warranted by the composition of the clay. In the moulds, settling again occurred, with the result that the body of the plates was found to consist of several well-marked layers. The lowest layer (*i.e.*, the top, or "face" layer of the plate) was very coarse and loose in structure and could easily be removed from the rest. It was found to have a total SiO_2-content of 70·04 per cent. Above this coarse layer was one somewhat finer in structure, but only in layers 3 and 4 was there a dense clay body. In subsequent casting tests with clay II., therefore, a stirrer was fitted into the slip container to prevent settling, whereupon cracks no longer appeared in the biscuit, but the circular patches now made their appearance in the glost-fired samples. In comparison with clay I., however, they were much less pronounced.

Casting Tests with Clay III. As with clay II., the slip in this case also was well stirred during the casting operation. With one exception, the glost-fired plates showed scarcely any signs of the circular patches.

Comparing the results of the tests with clays I., II. and III., a remarkable relationship is brought out. Clay I. with the smallest content of fine sand, gives the most marked evidence of "flashing," whilst with clay III., containing the highest proportion of fine sand, no "flashing" occurs. Clay II. occupies practically an intermediate position. Apparently, therefore, the lower the fine sand content, the greater the tendency to "flash." It was consequently to be expected that, with a kaolin rich in clay substance, "flashing" would be most marked. Such a material was clay V. containing

89% clay substance ; and upon carrying out tests with clay V. this forecast was amply confirmed. The typical patches were even more distinct than before.

Casting Tests with Clay IV. With this clay also, the patches were well defined. But whilst with the china clay the ring took no glaze whatever, with clay IV. it had a matt appearance and was rough to the touch. Clay IV. also had a high percentage of clay substance, but it also contained much mica. Whether this latter substance was responsible for the difference, could not at the moment be determined. In general, however, clay IV. confirmed the previous observations.

The large number of tests carried out with the five clays showed, therefore, that there is a certain relationship between "flashing" and the fine sand content of the clay. But since the mixture of sand and clay is a purely mechanical one, it was assumed to be possible to add sufficient fine sand to a pure clay to eliminate "flashing." Tests were accordingly carried out with clay V. and clay I.

Clay V. mixed with Fine Sand. A slip was made up to contain 90% china clay and 10% sand, and, on comparing the size of the patches with those obtained with pure kaolin, it was noted that the diameter of the central patch was greater, while that of the ring had become much smaller. And although the ring was still very rough, it was covered with an extremely thin film of glaze. On testing a similar mixture containing 70% clay and 30% sand, it was found that glost-fired plates made therefrom showed not the slightest trace of "flashed" surface. Similar tests carried out with clay I. mixed with sand confirmed the above results. The higher, therefore, the clay-substance content of the slip, the more pronounced is the tendency to "flashed" ware, and this tendency gradually disappears with an increasing sand content. This conclusion is directly contrary to K. Jakobs explanation and to the theory of C. Tostmann. The writer does not accept the explanation that "flashing" is due to a separation of the body ingredients, for if this were the case, the tendency to "flash" should decrease, and finally disappear, with an increasing clay-substance content. Precisely the contrary result was, however, obtained. According to F. Foerster, gypsum is washed out of the plaster at the point where the slip strikes the mould, causing vitrification in the biscuit oven. The rough ring should, therefore, contain more $CaSO_4$, or CaO than the remainder of the body. In order to decide this matter, two plates were cast with washed kaolin (concentration 2 : 5 as above) the slip being poured from a height of 40 cm. Both plates were biscuit fired, but only one was glazed and glost fired. Small pieces (about 2 grs.) were then taken (*a*) from the *edge* of the biscuit fired plate, and (*b*) from the surface of the rough ring on the glost-fired plate. Analyses of these two samples showed that the CaO content is practically identical in both samples. A further test was carried out as follows : A plate, measuring $15 \times 15 \times 2{\cdot}3$ cm. was formed, and biscuit fired, with clay V., the somewhat vitrified surface was removed to increase porosity, and a border of plastic material formed round the plate. Slip from clay I. was then poured on to the porous plate from a height of 40 cm. and the plate thus formed showed a normally flashed surface after glost firing. This was taken as clear proof of the fact that gypsum (colloid matter) has no effect upon the production of "flashed" surfaces.

The concentration of the slip is also an important factor. With an exceptionally thick slip, poured from a small height, "flashing" was reduced to a minimum. The same result was attained by pouring the slip into a narrow brass tube, the lower end of which was within 0·5 mm. of the bottom of the mould. Several plates were cast at the same time without the brass tube, for purposes of comparison. It was observed that, upon increasing the pouring height, (using the brass tube), the rough ring assumed progressively decreasing dimensions. These trials with the brass tube were repeated with clay I., similar results being obtained. In one case, the use of the brass tube reduced the width of the rough ring from 9 to 1 mm. In casting with the brass tube, the diameter of the ring was approximately that of the tube itself. Since the diameter of the tube was chosen sufficiently large (20 mm.) to allow

the stream of slip to pass through without touching the walls, new conditions must have prevailed at the moment when the slip struck the mould ; or in other words, the movements of the slip must have been affected by some disturbing factor or factors.

An attempt was then made to produce similar effects by other means, *e.g.*, by first soaking the plaster with water immediately before casting, and by inserting a glass disc in the bottom of the mould at the point where the slip fell.

The great speed at which the stream of slip struck and spread over the plaster precluded any possibility of adequate observations with the naked eye. The quantity of slip allowed to fall was, therefore, diminished, one large drop only being released instead of a continuous stream. In these experiments, a square sheet of plaster was used in place of the mould. Surprising results were obtained. A thin, circular film of clay about 18–20 mm. in diam. was formed by the drop of slip, and around this the clay lay in concentric circular ridges. The film of clay, which was extremely thin, dried immediately, whilst the thicker concentric ridges remained black for a time, the colour of the slip from clay I. having that colour. The ridge nearest to the centre was in all cases best developed ; the further removed from the centre, the less distinct were the rings. Thus the conditions observed were quite analogous to those found on the "flashed" portions of glazed ware. It was further discovered that the development of the clay ridges depended absolutely upon the concentration of the slip. The thicker the latter, the more clearly developed were the ridges and *vice versa*. Microscopic examination showed that, the thinner the slip, the denser the material in the clay ridges. These observations lead to the conclusion that a densification of the body actually takes place. It was also noticed that, where the initial drop had intentionally been chosen of large dimensions, the flashed spots, although very faint, could be unmistakeably recognised. With a very small initial drop on the other hand, the "flashing" disappeared completely.

The results showed conclusively that "flashing" occurs only when sufficient slip is allowed to fall into the mould. It does not occur if the stream of slip is cut off at the moment when the initial quantity has spread itself out. The succeeding column or stream of slip exercises pressure on the clay which has spread over the plaster, causing densification therein, which constitutes flashing. Summarised, the conclusions are :

1. "Flashing" can only occur when a clay slip is poured on to a porous surface, *e.g.*, plaster or a biscuit body. The greater the water-absorbing power of the surface, the more pronounced is the "flashing."

2. The greater the clay-substance content of a slip, the greater the tendency to "flash." With increasing quartz content this tendency diminishes gradually and disappears entirely with 30–40% of fine sand.

3. Neither the $CaSO_4$ of the plaster nor any other colloidal substance has any effect on "flashing."

4. "Flashing" is readily affected by purely mechanical means. The greater the pouring height, and the thinner the slip, the more prominent does the fault become. It can be diminished by introducing a disturbing factor into the spreading of the slip when it reaches the mould, *e.g.*, by (1) the use of a brass tube ; (2) inserting a glass plate in the surface of the plaster, and (3) reducing the absorbing power of the plaster by soaking it with water.

5. The origin of the fault is to be found immediately after the slip first strikes the plaster. It cannot, therefore, penetrate far into the material. The thickness of the layer is calculated to be from 0·08 to 0·12 mm. according to the clay used. It would, therefore, appear out of the question that whirling motion in the slip could be the cause of flashing.

6. In casting with a clay-sand mixture, a decided separation of the constituents takes place, particularly round the spot where the slip strikes the plaster, where much sand is deposited.

The theoretical explanation of these results is given at some length and is illustrated by diagrams.

The three most important constituents of a ceramic body are clay substance, felspar and quartz. The experiments carried out brought out clearly the close relationship between "flashing" and these three ingredients and the physical condition of the slip. Accordingly, "flashing" will be all the more intense in an earthenware slip: (1) the greater the clay substance content; (2) the smaller the quartz content; (3) the greater the felspar content; (4) the thinner the slip, and (5) the greater the pouring height of the slip. The alkali, *i.e.*, the soda, affects "flashing" only in so far as the consistency of the slip depends upon the amount added thereof. It follows then that, to remedy this troublesome fault, two courses are open: (1) modification of the body mixture; (2) modification of the casting methods. The former will, in most cases, be found the less practicable of the two. Attention should, therefore, be given to lowering the pouring height and rendering the actual pouring into the mould more precise. Experiments carried out with these objects in view gave completely satisfactory results. The earthenware body experimented upon contained: 53% clay substance, 33% quartz and 12% felspar. Ignoring the felspar, this body occupied a position where flashing disappeared. In addition, it was made up with soda and little water into a very thick slip. But the felspar would weaken the effect of the sand, so that with a low pouring height, flashing, although only faintly developed, was to be expected. The tabulated results show that a very faint but unmistakeable fault actually did occur; it also increased in size with an increasing pouring height.

With a pouring height of 2½ metres and a stream of slip 12 mm. in diameter, "flashing" was obtained with this body. With lower pouring, the composition of this body was such, that "flashing" was reduced to a minimum. By increasing considerably the pouring height, and with it the falling velocity of the slip, the quantity of fine sand and felspar deposited in the densified portions was altered in favour of the latter material. This may, therefore, be taken as a typical example showing how "flashing" is dependent upon the two factors: body composition and casting methods.

DRY-PRESSING REFRACTORY SHAPES.—L. W. Flood (*Brick*, **61**, 865, 1922). Attention is called to some of the problems met with in the manufacture of refractory ware of all sizes by the dry press process. A high percentage of plasticity is most essential for making dry press ware, since the pressure at times is equal to five or six thousand pounds per square inch. In general, the higher the percentage of moisture, *without excess*, the better the brick. This usually runs about seven per cent. Raw fire clay is usually crushed and then fed to a drying pan for grinding. Some type of mechanical feeder should be used in order to produce the best possible brick. If the clay is dry, a very small stream of water may be fed into the pan, so as to develop the full plasticity of the clay. In some cases, too much moisture at this point may curtail production; the point, therefore, requires careful attention. From the pan the clay should be fed to some type of screen. This is a very important operation in dry press manufacture, since too large a proportion of coarse sizes reduces the plasticity of the mass. The percentage of finely ground clay must be sufficient to fill the voids between the coarser particles, otherwise the homogeneity of the product will suffer. It is essential that a mechanical mixer be used just above the press to keep the fine and the coarse particles properly mixed. From this mixer the clay should have a perpendicular chute into the press; with a sloping chute, the coarser particles would tend to run ahead of the fine particles and destroy the uniformity of the mixture. Success depends very largely upon the maintenance of a constant, uniform and definite proportion of the various grain sizes in the body, this proportion, of course, varying with different clays. Uniformity is important since variations in the composition of the mixture entail variation in the requisite pressure applied. It is advisable to use as high a pressure as possible without producing pressure checks. Many of the advantages of this improved method are self-evident. The labour cost is reduced. The heat required for drying is smaller, since less

water is used. The investment in dryer buildings and equipment is less. There is also quicker turnover in drying. The resultant product is more uniform and exact in size, which is very important in the construction of some furnaces. With some clays, the refractoriness of bricks made by the dry press method has been increased by at least two cones. The uniform size of the ware permits of making the fireclay joints as thin as possible, thus increasing the life of the bricks. Finally, large refractory shapes made by this process are able to withstand sudden changes of temperature much better than the same shapes made by other methods.

Patents.

T–SHAPED BRICKS.—E. J. Frewen (*Pat. J.*, 1,784, 1923). No. 192,345, Nov. 29, 1921. Specially-shaped bricks, with shallow stems and two cavities, are described.

MOULDING POTTERY.—J. F. Gimson & Close Bros. & Co.(*Pat. J.*. 1,784, 1923). No. 192, 543, Dec. 3, 1921. Articles of pottery are moulded from clay slip in plaster moulds attached to the outer end of a hollow arm radiating from a hollow shaft, the slip being forced through the shaft and arm into the moulds by the action of centrifugal force set up by the rotation of the shaft.

ROOFING TILES.—R. Shadbolt (*Pat. J.*, 1,984, 1923). No. 192,549, Dec. 8, 1921. The tile described, when laid in position, has the appearance of two or more plain or curved tiles. It is made of uniform thickness and is provided with tongued and grooved side and head joints or locks.

TEA–POT SPOUTS.—S. Gibson (*Pat. J.*, 1,787, 1923). No. 193,320, Apr. 20, 1922. The extremity of the spout is curved downward, so that the lip is lower than the under side of the spout, thus preventing drip after pouring.

DRYING STOVES.—H. Goldstraw and R. T. Lewis (*Pat. J.*, 1,769, 1922), No. 187,330, July 19, 1921. In a pottery dryer comprising a rotary drum formed of two or more disks or wheels connected by bars from which sets of trays are hung, the trays are suspended by means of double S-shaped hooks. The shelves may thus be removed from the heated casing in which the apparatus is contained and goods removed from, or placed on them.

TEA-POT SPOUTS.—T. W. Bennett (*Pat. J.*, 1,770, 1922), No. 187,846, Oct. 29, 1921. The end of the spout is reduced in diameter or formed with a beading, to accommodate a short metal tube having a projecting curved lip.

CUP HANDLES.—R. Kay (*Pat. J.*, 1,770, 1922), No. 187,860, Nov. 15, 1921. The handles are disposed parallel to the base, so that the cups can be partially and completely nested one within the other. The handles may be of various forms.

MOULDING HOLLOW BRICKS.—H. Treitel and Kammerziegel Ges. (*Pat. J.*, 1,770, 1922), No. 187, 956, Oct. 10, 1922. Hollow bricks closed on all sides are obtained by first moulding the bricks with one end open and with burrs on the walls at the open end, and then pressing the burrs together until they meet.

ELECTRICALLY-HEATED CERAMIC WARE.—A. Steinhardt (*Pat. J.*, 1,771, 1922), No. 188,050, July 28, 1921. After being fired, an electrically heated ceramic vessel is fitted with a heating resistance provided with terminals, the heating body being then covered with ceramic material having the same coefficient of expansion as the resistance and composed of the same materials as the vessel but with the addition of fluxing materials, which lower its sintering temp. below that of the heating resistance. The whole apparatus is then fired again. For a vessel composed of 48% clay, 40% quartz, 12% felspar (the fluxes being the oxides of magnesium, sodium, lead, boron, together with a little NaCl and waterglass), and provided with a nichrom resister, the covering material may have the following composition by weight: 0·1 part Na_2O, 0·3 K_2O, 0·4 Mg O, 0·2 CaO, 0·4 Al_2O_3, 2·6 SiO_2 and 4 parts of the body used to make the vessel.

TEAPOTS.—E. W. Abram (*Pat. J.*, 1,772, 1922), No. 188,503, Oct. 20, 1921. A specially-shaped lid and spout are shown. A removable shutter, attached to the lid, extends across the orifice of the spout and is provided with horizontal slots. The lid, with shutter, rests on a ledge inside, below the spout. This ledge also serves to divert tea leaves during pouring.

MOULDING HOLLOW-WARE.—J. Plant (*Pat. J.*, 1,773, 1923) No. 188,994, Dec. 17, 1921. Egg-cups, and the like, are moulded between male and female dies, of which the male die is constructed in three relatively movable parts, adapted on being raised out of the female die to give threefold release to the moulded article.

TEAPOT SHAPES.—F. Tunnicliff (*Pat. J.*, 1,773, 1923). No. 189,018, Feb. 2, 1922. A shape is described which is designed to have no projecting parts liable to be broken. The body of the vessel is formed with four verticle side cheeks, with recesses between them, in two of which the handle and spout are situated. The lid is shaped so as to be flush with the flat top.

PRESSES FOR REFRACTORY MATERIAL.—B. V. C. Bourdeaux (*Pat. J.*, 1,779, 1923). No. 191,077, Dec. 29, 1922. The refractory mass is heated, while supported between the dies that are to shape it, by means of universally adjustable burners fed with a mixture of acetylene, hydrocarbon or producer gas and air or oxygen at a minimum pressure of 50 cm. of water. When the mass is sufficiently plastic, the burners are shut off gradually and pressure is applied by means of a die.

KILNS, OVENS, MUFFLES; FIRING TECHNIQUE, ETC.

THE UTILIZATION OF WASTE HEAT FROM CERAMIC KILNS BY MEANS OF RECUPERATORS.—Loeser (*Ker. Rund.*, **30**, 489, 1922). Best results are obtained with a recuperator if as much as possible of the waste heat is absorbed from the flue gases, leaving them just sufficient drawing power to ensure efficient draught conditions in the chimney. The importance of an automatic draught recorder cannot be over estimated. The construction of the recuperator must be such that the air and the flue gases can remain in indirect contact as long as possible, and the refractory dividing walls (of the flues, etc.) must allow the maximum transmission of heat. The walls must, therefore, not be too thick, but at the same time it must be remembered that they are in contact on one side with hot gases and on the other with cool air. They must consequently be capable of withstanding abrupt changes of temperature without cracking. The object of the recuperator being to preheat secondary air for the furnace, it is important to be able to regulate easily the mixture of gases and air so as to suit the requirements of any particular type of ware. The control of the kiln atmosphere is effected most satisfactorily by means of a simple apparatus for taking gas analyses. The recuperating system is best suited to intermittent kilns, the efficiency of the recuperator being greater, the higher the firing temperature and the longer the firing period. With this point in view, the various ceramic kilns may, therefore, be grouped as follows in the order of their suitability to the application of the recuperating system; Kilns for firing (*a*) Dinas bricks (temp. cone 17 in 120 hours); (*b*) Magnesia bricks and other refractory products; (*c*) Stoneware and mosaic tiles; (*d*) porcelain; (*e*) earthenware; (*f*) terra cotta.

BUHRER KILNS AND DRYERS.—(*Rev. Mat. Constr. Trav., Pub.*) No. 160, 4B, 1923). An account is given of the development from the original Hoffmann to the Zig-zag type of kiln.

BURNING IN UP-DRAUGHT FURNACE KILNS.—E. Petts (*Brick*, **62**, 125, 1923).

COLORATION, DISCOLORATION, AND OTHER BURNING EFFECTS.—E. Lovejoy (*Claywr.*, **79**, 38, 1923). The writer discusses the problem of "scum." An evanescent white coating, which appeared on the surface, even of vitrified bricks, after burning, was found, by analysis, to be

an alkaline sulphate. This surface coating was apparently due to the coal ash, its visibility and evanescence being the result of the action of ammonia in the atmosphere. It is very soluble and can easily be washed off.

FIRE BOXES AND GAS GENERATORS FOR GERMAN BROWN COALS.—Loeser (*Sprech.*, **56**, 131, 1923). The writer discusses the main principles to be observed in order to obtain the best results with German brown coals of the later formations, as distinct from the older, Bohemian variety.

TUNNEL OVENS.—A. E. Buch (*Südd. Tonind.*, **5**, 102, 1923). The general advantages of tunnel kilns are pointed out. The author has constructed a special type suited to works where insufficient room is available for a long tunnel. The Buch kiln is a double, U-shaped tunnel, in which the drying, firing and cooling zones can be isolated by means of refractory and iron dampers. The hot gases from the firing tunnel pass directly into the pre-heating tunnel running parallel with it. The length of the kiln is reduced by this means to 35 metres.

ON FIRING CIRCULAR AND TUNNEL KILNS FOR PORCELAIN.—E. Reutlinger (*Ber. D. K. Ges.*, **3**, 121, 1922). In a somewhat lengthy paper, the author gives the results of an extensive investigation, undertaken by the Kiln Section of the German Ceramic Society, with the object of reducing the more or less empirical methods at present employed to an orderly and systematic control of the firing operations. Measurements were taken in every case of the kiln temperatures, composition of the gases of combustion, and the draught pressures at various positions in the kilns. The results are admirably presented in nine graphical illustrations.

REPORT ON EXPERIMENTS WITH A GAS-PRODUCER.—Tamotsu Yashiro (*J. Jap. Cer. Ass.*, 361, 424, 1922). The author performed 83 experiments with a Dowson gas-producer at the Tsurumi plant of the Asahi Glass Co. The producer had a water-sealed Thwaite's ash-pit with a steam blower. It consumed 18,700 lbs. of a Hokkaido coal, consisting of 77·8% lumps, 21·9% medium lumps and 1·2% small coal, per day. It was poked five times an hour. (1) Temperature in the producer. The most suitable temp. of the coke-layer was 1,000°–1,100°C. When it was cooled below 800°C., the gas was useless; (2) proportion of steam and air. The best gas was produced when they were admitted to the blower in the proportion of 75·18% air and 24·82% steam by volume; (3) thickness of fire-bed. The best results were obtained when the layers of coke and coal were 18″—20″ and 17″—20″ thick respectively. Descriptions of the removal of ashes, velocity of air and steam passing through the fire-bed, and the pressure of steam are also given. S. Kondo.

RECORDING CALORIMETERS AND THEIR USE.—J. W. Wood (*Gas World*, **78**, 74, 1923).

TEMPERATURE MEASUREMENT IN THE CERAMIC INDUSTRY.—G. Keinath (*Sprech.*, **56**, 29, 1923). Methods of measuring and recording temperature in various types of kilns by means of ardometers are described and illustrated. The Ardometer is a radiation pyrometer of the Féry type, manufactured by Siemens and Halske. The radiant energy is collected by means of a lens and focussed on to a small black disc, to which a very fine thermo-element is attached. The latter is connected to a galvanometer.

BURNING BITUMINOUS SHALES.—(*Brit. Claywr.*, **31**, 317, 1923). The shale must be finely ground and thoroughly mixed before being made into bricks. After milling and screening, water is added to produce a stiff, plastic paste, which is then passed to a brick press. If the proportion of bituminous matter is large, a moderate amount of ground brick or sand should be added. This increases the porosity of the unfired bricks and greatly facilitates the burning. Only fully dried bricks should enter the kiln. The critical firing period occurs when the bricks are passing from a dull red to a bright red heat. The air supply at this juncture should be ample,

but not in too large quantities at a time. The best firing conditions are obtained with a 24-chamber kiln.

MECHANICALLY-FIRED KILNS.—(*Brit. Claywr.*, **31**, 246, 1922). An illustrated account is given of the successful application of a new method of firing to a 14-chamber Hoffmann kiln in Lancashire. The advantages are pointed out and the method of working is described.

TEMPERATURE MEASUREMENT IN THE CERAMIC AND GLASS INDUSTRY.—G. Keinath (*Sprech.*, **56**, 9, 1923). A general account is given of the various methods and of the different types of pyrometers used.

A NEW FIRING PROCESS.—(*Brit. Claywr.*, **31**, 275, 1922). An illustrated account is given of the Vesta system of firing bricks in a Hoffmann kiln.

ON SUBJECTIVE ERRORS IN FOCUSING OPTICAL PYROMETERS.—G. Keinath (*Stahl Eis.*, **43**, 9, 1923). For temperatures up to 1,100°, the red filter gives the best results in general, and for higher temp. the green filter is the better. Comparative measurements were made by a number of observers, some experienced, others entirely inexperienced, on three types of filament and radiation pyrometers. With the Holborn and Kurlbaum filament pyrometer inexperienced observers attained an accuracy of $\pm 10°$ for temp. of 800–1,000°, and $\pm 5°$ for temp. over 1,000°.

HEAT INSULATING MATERIALS.—W. N. Booth (*Gas J.*, **160**, 798, 1922 ; *Gas World*, **77**, 592, 1922). The importance of the correct choice and use of insulating materials is emphasised. Of the materials mentioned, 85% plastic magnesia has the lowest (0·00017 C.G.S.) and firebrick the highest (0·002) thermal conductivity.

AN AUTOMATIC KILN STOKER.—(*Tonind. Ztg.*, **46**, 2,018, 1922). An illustrated description is given of the Betsholz (Swedish) patent stoker for Hoffmann kilns. The apparatus consists mainly of an upright cylinder, containing a worm conveyor. The coal is fed to the cylinder from a small hopper.

A SLIDE RULE FOR USE IN ANALYSING GASES OF COMBUSTION.—A Gohmann (*Feuerung*, **11**, 49, 1922). The slide rule is described and illustrated.

ON GAS FIRING PORCELAIN KILNS.—C. Czerny (*Sprech.*, **55**, 483, 1922). Mainly a theoretical discussion on the use of formulae, etc. A criticism of the paper by Hollenweger appears on p. 541.

MUFFLES; THEIR QUALITIES AND CONSTRUCTION.—(*Corr. Cer.*, **3**, 183, 1922).

ON THE UPKEEP OF MUFFLES.—Pozzi (*Corr. Cer.*, **3**, 191, 1922).

Patents.

INSULATING MAGNESIA SHEETS.—Sachio Miki (*Jap. Pat.* No. 42,194, April 4, 1922). Coarse wire-netting is cut at many points and the ends of the wire threads are bent upwards or downwards. A paste composed of magnesia and a fibrous substance is applied to both surfaces of the netting. The sheet is used for insulating purposes. S. Kondo.

ROOFING-TILE KILN.—Tatsujiro Kishimoto (*Jap. Pat.* No. 43,050, July 11, 1922). A roofing-tile kiln has three chambers which are arranged so as to form an arch. In other words, the middle chamber is built over the passage between the other two. The waste-gases of the lower chambers are made to pass through the middle one. S. Kondo.

HEAT INSULATION FOR ROTARY KILNS.—O. Faber and H. V. A. Briscoe (*Pat. J.*, 1,762, 1922). No. 185,327, Sept. 5, 1921. The insulation is in the form of plates attached to the steel shell by screws or plugs of fusible metal which melts at a predetermined temp. Damage to the shell by overheating is thus prevented.

BRICK AND LIKE KILNS.—J. B. and A. H. Jones (*Pat. J.*, 1,763, 1922). No. 185,664. In a brick kiln comprising a number of separate chambers interconnected by a common flue, each chamber is surrounded by a peripheral flue communicating therewith through hobbed flues arranged between the fire places. In new kilns the peripheral flue may be built beneath the fire places.

CHIMNEY DAMPER REGULATOR.—A. Monnier (*Pat. J.*, 1,763, 1922). No. 185,667, Oct. 27, 1921. See TRANS. **22**, 9(A), 1923.

SUPERPOSED TUNNEL KILNS.—H. Harrison (*Pat. J.*, 1,771, 1922). No. 188,074, Aug. 2, 1921. A kiln for drying and firing bricks, etc., comprises superposed tunnels, the lower one for drying and the upper for burning. The lower drying tunnel may be divided into two sections, through which the trucks pass in succession before being elevated to the upper tunnel containing two rows of trucks.

CALCINING FURNACES.—H. Stehmann (*Pat. J.*, 1,772, 1922). No. 188,424, Aug. 26, 1921. A rotary furnace is described, which discharges into a shaft where the material is cooled by the air passing into the rotary furnace for combustion. The shaft is of such a size, and the air supply and the automatic discharge means are so controlled, that the air is heated to the ignition temp. of the fuel before entering the furnace.

TUNNEL KILNS.—T. Seedorff and L. E. George (*Pat. J.*, 1,772, 1922). No.188,488, Oct. 5, 1921. The tunnel furnace has a high temp. zone wider than the preliminary heating and cooling zones. The burner ports and outlet flues are arranged so that the heating gases flow diagonally across the high temp. zone, the direction of the flow being changed at intervals from one diagonal to the other. The air for combustion is heated in flues in the walls and roof of the cooling zone and passes thence through downtakes and flues to recuperators below the kiln.

FURNACES; AUTOMATIC DRAUGHT REGULATING.—F. B. Dehn (Pat. *J.*, 1,772, 1922). No. 188,517, Oct. 31, 1921. Description of an electrically operated, pressure controlled draught regulating device, applied to steam generator furnaces.

GAS-FIRED KILNS.—C. W. Thomas (*Pat. J.*, 1,776, 1923). No. 189,863, Sept. 6, 1921. Relates to the firing control of gas-fired continuous kilns, and comprises means for securing a desired distribution of the heating gases in a chamber, and for preventing back draught between one chamber and another. Each chamber has outlet ports in the floor and gas and air inlet ports arranged alternately along one side. These latter ports are in communication with a gas flue and with the floor flue of the preceding chamber. Stoppers are used to regulate the flow of gases through the ports. To prevent back draught between the last preheating chamber and the next of the series a strip of paper is laid across the air ports of the latter.

TUNNEL KILNS.—Woodall, Duckham and Jones, Ltd., A. M. Duckham and A. T. Kent (*Pat. J.*, 1,777, 1923). No. 190,393, Feb. 24, 1922. Addition to Spec. 177,561. The baffles, which co-operate with the walls erected on the trucks, depend from the roof to increasing extents in the direction in which the trucks travel, so that some of the sand placed on the walls is swept off, the tightness of the compartment being thereby assured. Mechanism is provided for centring the trucks prior to moving them forward one step, and for staggering them to bring the walls on the trucks into contact alternately with opposite sides of the kiln.

FIRING BRICKS.—J. B. Monnier (*Pat. J.*, 1,781. 1922). No 191,734, Jan. 10, 1923. In firing, bricks may assume four different states according to their compositions and the temperatures to which they are subjected. In the third state, vitrification becomes complete, and distortion takes place owing to unequal distribution of molecular force. On cooling, the brick becomes very dense and has a crushing strength of 1,200 kg. per cm.^{2} In order to produce bricks which have passed through this stage and which are

substantially regular after cooling, the brick is shaped with convex sides to compensate for distortion. The bricks are spaced apart in the kiln during firing.

FURNACE LININGS.—H. Hindley and V. Walton (*Pat. J.*, 1,783, 1923). No. 192,158, Oct. 27, 1921. Porous bricks or blocks, on which liquid or colloidal fuel may be sprayed in a furnace, are obtained by burning a mixture of 3 parts by measure of dry fireclay, to 1 part of sawdust, peat, cork dust, or other finely-divided combustible material. The bricks are made preferably with a number of grooves across one of the narrower faces and one end, to admit air for combustion of the fuel.

GLAZES, ENAMELS.

A CURIOUS DEFECT IN SALT GLAZING.—(*Brit. Claywr.*, **31**, 319, 1923). Salt-glazed drain-pipes showed the remarkable defect of being devoid of glaze at the sockets. After investigation, it was found that the defect was due to the irregular distribution of the draught in the kiln, and by enlarging the chimney flue and building a uniformly perforated floor, the pipes were glazed perfectly.

GLAZED WARE,—VI. THE ENGOBE OR SLIP CASTING.—(*Brit. Claywr.*, **31**, 320, 1923).

THE MICROSTRUCTURE OF ENAMELS.—L. Vielhaber (*Ker. Rund.*, **31**, 47, 1923). Contrary to results reported by Menzel, the author found that all enamels consisted of a glass containing a network of bubbles. The latter proved to be always larger in size in the ground coat than in the surface enamel, the mean diameter for the former being 0·02 mm. and for the latter 0·001–0·005 mm. Experiments were carried out to test the effect of increasing the clay content and the CoO content, and of varying the fineness of grinding on the nature, size, and number of the bubbles, a commercial enamel (composition not stated) containing 0·51% CoO being taken as a basis. The results are tabulated as follows :—

SERIES I.

Ground-coat with 0·51% CoO.

No.	Grind.	Bubbles.	Quality.
1	coarse	large	I.
2	fine	small	II.

Ground-coat with 0·51% CoO. + 6% clay.

5	coarse	small	I.
6	fine	large	II.

Ground-coat with 0·51% CoO. + 10% clay.

7	coarse	uniform	I.
8	fine	medium size	II.

SERIES II.

Ground-coat with 80·85% CoO.

No.	Grind.	Bubbles.	Quality.
3	coarse	large	II.
4	fine	small	I.

Ground-coat with 0·85% CoO. + 6% clay.

9	coarse	small	II.
10	fine	large	I.

Ground-coat with 0·85% CoO. + 10% clay.

11	coarse	uniform	II.
12	fine	medium size	I.

In the ordinary ground coats the bubbles assume a hemispherical form in contact with the iron. The effect on the adhesive capacity of substituting other oxides for cobalt was also studied and it was found that the metals, arranged in a descending scale, give the following series : cobalt, nickel, chromium, zirconium, iron, manganese, copper, tin, titanium, arsenic. In enamels containing cobalt, nickel, or manganese the bubbles show a highly uniform development, and it is therefore concluded that they have a direct influence on the adhesive capacity, which quality depends both on the coefficient of expansion and on the modulus of elasticity.

Patents.

ENAMELLING CHINA, ETC.—E. Grice and A. E. Hewitt (*Pat. J.*, 1,737, 1922). No. 176,667, Mar. 9, 1921. Openings, such as eyes, in china cats,

dogs, etc., and other forms of decorative china, porcelain, etc., are closed by glaze during the usual process of glazing to enhance the effect of transmitted light.

ENAMEL SPRAYER.—N. Meurer (*Pat. J.*, 1,745, 1922). No. 179,216, Nov. 27, 1920. See Abstract, TRANS. **21**, 50A, 1922.

"COLD" GLAZES.—K. Friedrich (*Pat. J.*, 1,776, 190,267). No. 190,267, Sept. 25, 1921. A coating composition to be applied to concrete, sandstone, clay, brickwork, etc., consists of water and finely sifted cement with a waterproofing ingredient such as a bituminous, resinous, or wax-like substance, or a metallic soap. Suitable soaps are obtained by using a mixture of alkaline soap with ammoniacal zinc solutions or ammoniacal or alkaline solutions of copper, lead, tin, chromium, or aluminium hydroxides, or a mixture of calcium suboleate and aluminium sulphate.

COLOURS, DECORATIVE PROCESSES, ETC.

THE APPLICATION OF THE OSTWALD COLOUR THEORY TO THE DECORATION OF PORCELAIN.—W. Funk (*Ber. D. K. Ges.*, **3**, 77, 1922). The objections raised by opponents of the colour theory, led by Prof. H. Hildebrandt, are first dealt with. The writer then outlines the progress made at the Porcelain Works of Meissen, in applying Ostwald's principles to works practice. For instance, Meissen "lemon yellow" corresponds to 001a on the colour scale, "yellow-red" to 21 pe, "border-blue" to 50 pa, etc. (*c.f.* TRANS. **20**, 89 A, 1921).

LUSTRED POTTERY; ANCIENT AND MODERN.—G. M. Forsyth (*Pot. Gaz.*, **48**, 95, 1923). Two distinct classes are recognised: true lustres fired in a reducing atmosphere, and false lustres fired in an ordinary atmosphere in muffle kilns. The history of the art is outlined, and there are five illustrations of Italian and Hispano-Moresque ware. The manufacturing process is also briefly described.

NOTES ON THE GELATINE USED FOR PREPARING CERAMIC PHOTOGRAPHS.—C. Fleck (*Sprech.*, **56**, 133, 1923). The gelatine must be completely soluble in warm water. A hard variety is necessary for pigment photographs which have to be fired on, though it is liable to be streaky. But this can be avoided if a little liquid fish glue is added to the chromate mixtures. The chromate-gelatine mixture should not be boiled longer than 15 minutes.

PATENTS.

THE UNDER-GLAZE COLOURING PROCESS.—Daigoro Fukuoka (*Jap. Pat.* No. 43,176, July 31, 1922). Numerous shots of clay or other substance are soaked in wax, which has or has not been mixed with pigment, and are filled in a vessel, so as to embed a pottery body in them. By warming the whole vessel, the wax adheres to the surface of the body. The body may then be covered with a net which has previously been soaked in wax, coloured with pigment or not, and warmed again. The body is then painted with under-glaze colour and fired in a kiln. S. KONDO.

PLANT AND MACHINERY, ETC.

COLLOID MILLS AND ULTRA FILTER PRESSES.—(*Can. Chem.*, **7**, 1, 1923). An editorial review of the development of the Plauson patents. The Plauson ultra-filter press, without which the colloid mill would be handicapped, should prove of use for dehydration purposes in the ceramic industry.

BELT CONVEYORS AND BELT ELEVATORS.—F. V. Hetzel (*Ind. Man.*, **9**, 150, 1923). A review of the book of above title.

TILE PRESSES.—(*Tonind. Ztg.*, **47**, 47, 1923). An illustrated description is given of a press recently put on the market by Gebr. Sprengler, of Uetersen. It is a round table press, six or more moulds being arranged concentrically in the table. The press is capable of turning out from 11,000 to 14,000 tiles, measuring 15×15 cm., in an 8-hour day.

A NEW ELUTRIATOR FOR RAPID USE.—T. M. Lowry (*Trans. Faraday, Soc.*, **18**, 32, 1922). The apparatus is based on Boswell's elutriator, and is modified in two respects only : (1) the lower portion of the vertical tube is tapered smoothly from 25 to 2 mm., and is then sealed on to a 2-mm. capillary about 100 mm. long ; (2) this capillary carries a tap instead of a screw-clip. The method of operation is described.

LIFE TESTS ON PLATINUM—PLATINUM-RHODIUM THERMO-COUPLES.—C. O. Fairchild and H. M. Schmitt (*Chem. Met. Eng.*, **26**, 158, 1922).

UNLOADING COAL AND SAND.—H. Hermann (*Tonind. Ztg.*, **46**, 983, 1922). An illustrated description of unloading apparatus.

DISINTEGRATORS FOR CRUSHING SAGGARS AND FIREBRICKS.—(*Brick Pot. Tr. J.*, **30**, 232, 1922). A description (2 illus.), of the "Lightning Crusher and Pulveriser."

THE COLLOID MILL.—A. Forster and J. Keilly (*J. Soc. Chem. Ind.*, **41**, 435R, 1922). An account of the Plauson mill.

TILE PRESSES.—(*Tonind. Ztg.*, **47**, 47, 1923 ; *Ker. Rund.*, **31**, 37, 1923). An illustrated description of a new press manufactured by Gebr. Spengler, of Uetersen, is given.

THE NEW HAMMER-MILL "IMPERATOR."—(*Allg. Tonind. Ztg.*, **42**, No. 4, 2, 1923). The mill consists of a cylindrical casing in which is a revolving shaft with hammers attached. The casing is fitted at the bottom with a grating, which can be regulated according to the size of material required. The mill is capable of dealing with material from egg to cocoa-nut size. The hammers are not of the rigid type, so that, on meeting with hard, foreign matter, *e.g.*, pieces of iron, they are turned aside.

Patents.

ROLLER AND RING MILL.—D. J. G. Miller and K. A. Lloyd (*Pat. J.*, 1,768, 1922). No. 186,956, May 13, 1921. Description of a machine for grinding slag, cement, rock, etc.

FILTER PRESSES.—J. Newton (*Pat. J.*, 1,768, 1922). No. 187,072, Aug. 11, 1921. A cloth tape is attached in a suitable manner to the inner end of each nozzle. The metal pipes fixed to the taps are passed through the nozzles and the tubes.

BRICK-MAKING MACHINERY.—S. Sullivan (*Pat. J.*, 1,770, 1922). No. 187,780, Aug. 30, 1921. The apparatus consists of a feed hopper, an extrusion mill, a take-off device, a rotary self-lubricating cutter, a reciprocating stamp, a conveyor, a push-off device to deliver on to a travelling band, and gearing for controlling the action of the various parts.

BRICK MOULDING MACHINE.—A. Johnson (*Pat. J.*, 1,770, 1922). No. 187,852, Nov. 3, 1921. Relates to the type in which the clay is pressed between upper and lower plungers.

BALL MILLS.—R. E. H. Pomeroy (*Pat. J.*, 1,771, 1922). No. 188,173, Oct. 13, 1921. Describes a method of admitting a current of air to carry off the finer particles.

ROOFING-TILE MACHINES.—H. D. Fitzpatrick (*Pat. J.*, 1,773, 1923). No. 188, 776, Aug. 17, 1921. Relates to machines of the type comprising a rotary polygonal mould drum. A main and a secondary pressing-ram are provided, both acting simultaneously and normally to the drum faces.

PRESSES FOR MOULDING SAGGARS.—R. H. Carr and J. P. Guy (*Pat. J.*, 1,776, 1923). No. 189,890, Sept. 13, 1921. Description of a press for making saggars, sinks, crucibles, etc.

REMOVING MOULDED TILES.—W. P. Thompson (*Pat. J.*, 1,780, 1923). No. 191,347, Sept. 24, 1921. Tiles are removed after moulding by jaws

carried on a rotatable frame. Means are provided for delivering the tiles into an incline.

BRICK-MOULDING MACHINES.—E. N. Sutcliffe and Sutcliffe, Speakman & Co. (*Pat. J.*, 1,780, 1923). No. 191,453, Oct. 10, 1921. In a rotating table press (*Spec.* 14,937/02) the first motion shaft is geared directly to a main shaft, which actuates the press elements, and to a countershaft which operates the ejecting mechanism. Means are provided for removing the ejected bricks from the mould table.

BRICK-MOULDING MACHINES.—C. H. Whittaker (*Pat. J.*, 1,783, 1923). No. 192,307, Mar. 7, 1922. Specifications 3481/84 and 7456/93 are referred to. The lower plunger is positively reciprocated at least twice during the compressing operation, in order to smooth the surface of the brick.

MOULDING MACHINE.—J. Benton (*Pat. J.*, 1,785, 1923). No. 192,886. A number of articles of pottery are moulded simultaneously in a machine comprising a one-piece mould with a number of pockets and a number of forming tools arranged circularly.

BRICK-CUTTING MACHINE.—L. N. Dyhrberg (*Pat. J.*, 1,786, 1923). No. 193,075. A lengthy description is given of a machine, in which the cutting table is set in motion by the pressure of the extruded clay bar.

BRICK-MAKING MACHINES.—L. N. Dyhrberg (*Pat. J.*, 1,787, 1923). No. 193358/9, Aug. 18, 1921. Machines are described of the type in which the stream of clay from the pug-mill is utilized to set in action the cutting mechanism.

BRICK-HANDLING APPARATUS.—L. N. Dyhrberg (*Pat. J.*, 1,787, 1923). No. 193,360, Aug. 18, 1921. Means for stacking and dealing with cut bricks in bulk, as received from the cutting machines, are described.

III.—FINISHED PRODUCTS: TESTING, ETC.

STRENGTH TESTS ON ELECTRIC INSULATOR MATERIALS.—A. Schob (*Mitt. Materialprüfungsamt, Berlin*, **40**, 156, 1922). The effect of varying the degree of pressure applied in making, and of the condition of the surface on the strength of standard rods was studied. Tests were carried out at ordinary and at higher temperatures. At room temperature, the pieces were tested for (1) bending strain, (2) resistance to impact, (3) resistance to tension (by means of a special apparatus), and (4) hardness (by a modified Brinell test). The results are tabulated in full (9 tables). It was found : (*a*) that there exists no marked and uniform relationship between the degree of pressure applied and the physical properties tested ; (*b*) that the rods which had a surface "press-skin" gave higher results than those without such.

AN UNUSUAL FAULT IN FLAT ROOFING-TILES.—Glauss (*Tonind. Ztg.*, **47**, 137, 1923). An experience is described in which trouble was encountered in the form of cracks in the tiles after firing. An unusual feature was the distinctly vitrified appearance of both surfaces of the cracks, though the remainder of the body was of the ordinary porous type. From a discussion by a number of experts, it is concluded that the fault was due to rapid cooling of the tiles while at a high temp. causing local shrinkage.

THE DURABILITY OF REFRACTORIES.—W. J. Rees (*Gas World*, **78**, 19 (Coking Sect.), 1923. The durability of refractories depends upon the following factors : (1) The softening temperatures ; (2) the mechanical strength at normal and high temp. ; (3) the thermal or reversible expansion ; (4) the permanent expansion or contraction ; (5) the resistance to abrasion ; (6) the resistance to slag attack ; (7) the permeability to gases and vapours at high temp. ; (8) the resistance to abrupt changes of temp. at high and low temps. ; (9) the changes in properties after prolonged heating. The relative importance of these factors varies with the type of furnace. Resistance to

abrasion and spalling is largely a question of texture. Resistance to slag attack depends upon chem. comp. and texture. The deformation temp. for whole bricks is from 50–100° lower than for fragments of bricks, as indicated by the standard method of testing. Both a high quartz conversion and high silica concentration are desirable if maximum durability of refractories is to be obtained. The special advantages of silica materials are pointed out. In conclusion, the author emphasizes the necessity of collaboration between makers and users of refractories.

UNDER-LOAD TESTS ON REFRACTORY BRICKS AT HIGH TEMPERATURES.—E. Sieurin and F. Carlsson (*Ber. D.K. Ges.*, **3**, 53, 1922). See TRANS. **21**, 77 (A), 1922.

ON THE WEATHERING OF BUILDING STONES.—M. Gary (*Mitt. Materialprüfungsamt, Berlin*, **40**, 42, 1922). A number of stones of various types and shapes were exposed to the weather for considerable periods at four different places. The tests were commenced in 1908, but complete data are not yet available. The stones tested include : granites (4 pieces), gabbros, basalts, diabase (7 pieces), sandstone, quartzite, graywackes (5 pieces), marbles, limestone, tuff (8 pieces). Some of the available results up to 1920 are tabulated.

POROSITY VII. THE DETERMINATION OF THE POROSITY OF HIGHLY VITRIFIED BODIES.—E. W. Washburn and E. N. Bunting (*J. Amer. Cer. Soc.*, **5**, 527, 1922). The limits of accuracy of the ordinary laboratory research type of porosimeter are discussed and the principles of design indicated. A new type is described—the McLeod Gauge Type of porosimeter—with which the pore vol. of any test piece may be determined directly to within 0·01–0·02 cc. Tests on eight pieces of electrical porcelain indicated a porosity of $0 \pm 0{\cdot}01\%$. The result was confirmed by dye penetration tests. The general method for measuring the porosity of full size bricks is also figured and described (*c.f.* TRANS. **21**, 72A, 1922).

BRICKS FOR CUPOLA FURNACES.—(*Brit. Claywr.*, **31**, 255, 1922). The properties and requirements of suitable bricks are outlined.

BRICKS FOR CHEMICAL FURNACES.—(*Brit. Claywr.*, **31**, 275, 1922). Three types of furnace are considered, viz. : oxidation, reduction and calcination furnaces. The following points demand consideration in deciding the type of refractory material : (*a*) The maximum temp. to be reached If this exceeds 1,300°C., the refractoriness of the bricks is of the greatest importance ; (*b*) the variations in temp. These are often very serious in oxidation furnaces. The danger of spalling and cracking is greatest in small furnaces, since the larger ones require much longer time to empty and refill ; (*c*) the chemical action of the materials, whether acid, neutral or basic. For corrosive materials the lining of the furnace should be of close-textured, non-porous bricks ; (*d*) the abrasive action of the charge. This is important in shaft furnaces in which the descending charge may rapidly wear away the lining. The bricks should again be non-porous, close-textured and well-graded ; (*e*) constancy of volume when in use. Silica tends to expand in use, whilst fireclay, magnesia, dolomite, alumina, etc., tend to contract.

ELECTRICAL TESTS FOR POROSITY OF ELECTRICAL PORCELAIN.—J. E. Shrader (*Electric J.*, **19**, 118, 1922). The most important property of electrical porcelain is its dielectric strength, which depends largely upon moisture absorption due to porosity. If subjected to a high-voltage test, a good insulator should flash over, but if the piece has absorbed moisture to any considerable extent, the result will be a puncture. Four insulators were tested to determine how the power factor and resistance are affected by moisture absorption. They were tested in an oven over night at 200°C. After cooling, they were partly filled with mercury and floated in a shallow tray of mercury. With the mercury as electrodes forming close contact, measurements for power factor were made with a sensitive electrostatic wattmeter, and the resistance was determined with a sensitive high resistance

galvanometer. The mercury was then replaced by water and the measurements were repeated. If this was done immediately, the values were the same as when mercury contact was used. The insulators were then allowed to soak in water and the tests were repeated at intervals over seven days. The results showed that the power factor determination is a sure indication of moisture absorption. It is a more precise test than resistance measurement, which is inadequate to distinguish between two insulators of superior grade. It has a direct relation to dielectric strength and is dependent upon moisture absorption. This was confirmed by dye tests.

THE EFFECT OF VARYING THE POTASH AND SODA FELSPAR CONTENT, AND OF DIFFERENT FIRING TEMPERATURES, ON SOME OF THE PHYSICAL PROPERTIES OF HARD PORCELAIN.—E. Roth (*Sprech.*, **55**, 533, 1922). The body tested had the following rational analysis : 50 parts by wt. clay substance, 25 parts quartz and 25 parts felspar. Two sorts of Norwegian felspar were used, a potash felspar (12·9% K_2O) and a soda spar (11·8% Na_2O). The test pieces were fired in an industrial oven to cones 9–10 (1,290°C.), 11–12 (1,335°), 13 (1,380°), 14 (1,410°), 15 (1,435°) and 15–16 (1,442°). The various reactions, which take place between the body constituents during firing, are discussed. With regard to the results of the investigation in general, it may be said that the technical qualities of porcelains of the type examined are definitely improved by firing beyond cone 14, and that, to produce ware having the same physical qualities, the firing temp. for the soda felspar bodies is about 2 cones lower than that required for potash bodies.

ON THE ABSORPTION-TEST OF COMMON BRICK.—Seiji Kondo and Masaru Nakao (*J. Jap. Cer. Ass.*, 363, 527, 1922). Elaborate experiments on the methods of testing the water absorption of common bricks have been carried out for the National Committee on Industrial Standards. (1) Samples. Samples were supplied by the Nippon Brick Mfg. Co., Tokio, and the Osaka Ceramic Industries Co., Osaka, two of the largest brick manufacturers in Japan. They classify their common bricks into 8 and 6 grades respectively, according to the degree of burning. The porosities of the Tokio bricks ranged from 27·04% to 36·87%, while those of the Osaka bricks were 23·27—32·61%. (2) The rate of drying. The rate of drying of bricks, which were previously soaked in water for 48 hours or longer, was studied to find the best method for drying bricks, with the following results : (*a*) the time required for drying decreases as the temperature rises, *e.g.*, the mean values for the Tokio bricks were 7·25, 6·94, 6·63, 5·13 and 4·13 hours at 100°, 110°, 120°, 130° and 140°C. respectively ; (*b*) the rate of drying diminishes rapidly as the content of water decreases, and (*c*) the time required for drying does not correspond with the order of absorption. (3) The relation between the temperature of drying and the dry weight of brick. If bricks are considered dry when the weight of brick has become constant for two hours, as is usually the case, the dry weight is affected by the temperature in the drying oven, unless a very sensitive balance is used. Thus, the eight grades of the Tokio bricks had 0·08%, 0·06%, 0·01%, 0·01% and 0·00% moisture on an average after drying at 100°, 110°, 120°, 130° and 140° C. respectively, and the six grades of the Osaka bricks showed 0·17%, 0·07%, 0·01% and 0·00% moisture on an average after drying at 115°, 120°, 125° and 130°C. respectively. The above results indicate that bricks should be dried at a temperature not less than 125°C. (4) The weighing of dried bricks. If we weigh dried bricks as hot, the observed weights must be a little less than those obtained by weighing them after they have been cooled in desiccators. The difference amounted to 0·39 grams or 0·02% for the Tokio bricks (average of 80 weighings) and 0·55 grams or 0·02% for the Osaka bricks (average of 36 weighings). Therefore, hot bricks may be weighed in the absorption-test. (5) The rate of absorption. In order to observe the rate of absorption, the dried Tokio bricks were laid flat in a vessel and then water was poured into it to a certain maintained level. After 24 hours, the level was raised to a certain height which was maintained for a further 24 hours. During these 48 hours, the progress of

absorption was studied by weighing the bricks 15 to 18 times. The results, in short, are as follows: (*a*) the depth of water evidently affects the absorption, *e.g.*,

Depth of water in cm. ..	1·0	2·9	5·5	6·8	
Mean absorption in 24 hrs.	14·26%	14·19%	14·15%	14·01%	
Depth of water during first 24 hours in cm. ..	1·0	1·0	2·9	5·5	8·8
Ditto during next 24 hours in cm.	8·8	35·8	8·8	8·8	8.8
Mean absorption in 48 hrs.	14·58%	14·49%	14·41%	14·42%	14·29%

The mean thickness of the bricks was 5·8 cm.; (*b*) the progress of absorption is not materially affected by the degree of burning, and (*c*) the absorption in the first hour amounted to 91·1—97·3% of the whole. (6) Method of soaking. Various methods of soaking were compared as described in the preceding paragraph. but without weighing bricks during the 48 hours of testing. (*a*) The best method of soaking is to dip one cm. of the bricks, placed flat, for 24 hours and then to immerse them entirely, their upper surfaces being 3 cm. below the water-level; (*b*) absorption is influenced by taking out the brick for weighing during the testing time; (*c*) the absorption of bricks which had been soaked in water for 48 or 72 hours increased by 3·76—5·00% in the Tokio bricks and by 3·10—4·29% in the Osaka bricks when they were boiled for five hours; (*d*) tests in which bricks were laid flat on a stretcher or header in water showed that the best way is to lay bricks flat. (7) Proposed method for absorption-test. The test bricks must first be weighed and then dried in an air bath at a temperature of 125° to 135°C. for two hours. On removing them from the drier they must be reweighed at once. If the second weight closely agrees with the first, they may be considered dry, but if it does not, they must be returned to the drier and dried for an additional two hours. If the third weight checks the second they are considered dry. In case of doubt, the bricks should be subjected to further two-hours drying treatment until check weights are obtained. After the dry weight is obtained, the bricks must be cooled to room temperature and laid flat in a vessel. The bricks must then be submerged in water 1 cm. deep, and the water-level must be kept constant for 24 hours. Then more water must be added to the vessel so as to immerse the bricks entirely in it, their upper surfaces being 3 cm. below the water-level. These conditions must be maintained for a further 24 hours. The bricks must then be re-weighed after the surplus water has been quickly wiped from their surfaces with a wet cloth which has been wrung hard. All weighings must be read to the nearest gram. S. KONDO.

PHYSICAL CHARACTERISTICS OF SPECIALIZED REFRACTORIES.—M. L. Hartmann and W. A. Koehler (*Trans. Amer. Electrochem. Soc.*, **40**, 457, 1922). A series of tests to determine the transverse breaking strength of each of ten refractories at 20° and 1,350°C. was carried out. In the design of refractory parts for furnaces, muffles, etc., it is important to know the transverse breaking strength of the parts used. A material with a high transverse strength is obviously desirable in a muffle or semi-muffle types of furnaces, when heat is transmitted through the refractory walls; the greater the strength, the thinner may be the wall, giving better conditions for heat transmission. Within the range of temperature covered by these experiments, chrome bricks were affected most by increase in temperature, decreasing to one sixty-third of their cold breaking strength. Bauxite fell to one-thirteenth, magnesia to one-tenth and fireclay to one-sixth. The carborundum refractories tested (recrystalized carborundum—Refrax; bonded carborundum—Carbofrax, A, B and C) showed very high moduli of rupture both hot and cold, and maintained high values even at 1,350°. Two of these—Refrax and Carbofrax A—actually showed an increase in strength at the higher temperature, but there is undoubtedly a maximum temperature beyond which their cross-breaking strength decreases. Preliminary work indicated that this lies between 1,350 and 1,500° for the bonded varieties, but it is

considerably higher for the recrystallised silicon carbide type (Refrax). This is to be the subject of further investigation. A description of the crushing mechanism and of the furnace is included.

THE NEED FOR MORE REFRACTORY HEAT INSULATORS.—R. D. Pike (*J. Amer. Cer. Soc.*, **5**, 554, 1922). A proposal is put forward for carrying out the necessary research for the production of more highly refractory insulators, and it is suggested that refractory manufacturers should interest themselves in such work. The need of a simple apparatus, called for convenience a conductometer, for carrying out routine investigations of thermal conductivity on refractory materials is pointed out and the design of one such apparatus is outlined. The suggested method is similar in most respects to the standard calorimetric method, but the flow calorimeter is replaced by a standard thermal resistor.

IV.—MANAGEMENT, ORGANISATION, COSTING, ETC.: COMMERCIAL.

STANDARDISED COSTS FOR CLAYWORKERS.—A. Baruch (*Claywr.*, **79**, 36, 1923). The first of a series of 13 chapters covering the subject of Cost Accounting. The first instalment deals with the meaning of cost keeping and its need.

RESEARCH IN INDUSTRY.—(*Ind. Man.*, **9**, 142, 1923). The importance of scientific research to modern productive methods is illustrated by an account of the Laboratory of the G.E.C. at Wembley.

AN UNCOSTLY COST-ACCOUNTING SYSTEM.—W. A. Barron (*Brick*, **62**, 30, 1923). An account is given of a complete system, which has proved highly successful in practice. Only four forms, specimens of which are illustrated, are required.

ACCOUNTING SIMPLIFIED.—G. W. Greenwood (*Brick*, **62**, 39, 1923). An introduction to a series of articles which give details of a system of accounting both cheap and efficient.

STANDARDISATION IN COST ACCOUNTANCY.—(*Ind. Man.*, **9**, 177, 1923). A short abstract of a paper read by H. G. Jenkins at the second Annual Conference of the Institute of Cost and Works Accountants.

INDUSTRIAL ACCIDENTS IN RELATION TO TEMPERATURE.—H. M. Vernon (*Eng. Ind. Man.*, **8**, 371, 1922). Taken from Report No. 19 of the Industrial Fatigue Research Board.

GRAPHICAL REPRESENTATION OF COSTS (BRICK AND TILE WORKS).—(*Rev. Mat. Constr. Trav. Pub.*, No. 159, 179 B, 1922 and No. 160, 7 B, 1923).

ACCOUNTING SIMPLIFIED.—G. W. Greenwood (*Brick*, **62**, 127, 1923). The article (2nd of a series) deals with (*a*) closing the operating register, and (*b*) recapitulation of expenses.

KEEPING KILN RECORD CHARTS.—(*Brick*, **62**, 138, 1923). An illustration is given of a Kiln Record measuring $5\frac{1}{4} \times 8\frac{1}{4}$ inches. The cards are of the loose-leaf type, and provide for recording such data as the kiln number; date and hour when lighted; time of water-smoking; heating up and soaking periods; number of bricks set; amount of coal used to fire 1,000 bricks, etc.

CLAY PRODUCTS PLANTS IN CLEVELAND, OHIO.—(*Claywr.*, **79**, 24, 1923). A well-illustrated account is given of 18 plants located in Cleveland. Some unusual features in equipment and methods of operation are described.

V.—GLASS: GENERAL.

HEAT-ECONOMY IN THE GLASS INDUSTRY.—(*Sprech.* **56,** 44, 1923). Extracts are given from reports, issued by the "Thermo-Technical Advisory Bureau" of the German Glass Industry, on thermo-technical investigations on (1) a hollow glass furnace, and (2) a plate-glass furnace.

ABRASIVES AND POLISHING POWDERS FOR GLASS.—J. W. French (*Trans. Faraday Soc.*, **18,** 42, 1922). The action of an abrasive is discussed and explained. The rate of abrasion depends upon: (1) the size of the grains; (2) the force of impact, which depends upon the load on the tool, its momentum, its speed of translation, and its grip on the grains; (3) the number of impacts per unit of time. A ground-glass surface consists of small depressions, the surfaces of which are polished. In an optically-worked piece of glass, the surface is not only polished, but is free from depressions. The polishing process, therefore, involves a continuation, but in a different manner, of the abrasion, and a reduction of the level of the protuberances until the bottoms of the cavities have been reached.

THE REMOVAL OF A HISTORICAL GLASSWORKS.—(*Pot. Gaz.*, **48,** 276, 1923). An account of the works owned by J. Powell & Sons, which has been removed from Whitefriars to Wealdstone, Harrow.

GLASS ETCHING.—L. Springer (*Glashütte*, **53,** 3, 1923). Continuation of a long and detailed paper on glass painting and etching, emphasis being laid on the chemical basis of the subject.

SHAPING ARTICLES OF FUSED QUARTZ.—W. Schuen (*Tonind. Ztg.*, **46,** 1,155, 1922; *Ker. Rund.*, **31,** 22, 1923). Pure, washed sand is melted in an electric furnace into a short, thick-walled tubular block. The electrodes and the resistor are then removed and the furnace is swung round horizontally. Quartz tubes are drawn in a manner similar to that applied in making glass tubes. Compressed air is admitted at one end of the block, the other being gripped firmly with suitable forceps. The actual drawing operation is rendered more difficult than is the case with glass, owing to the higher working temperature and the more rapid cooling. A still more difficult operation is the shaping of such articles as dishes, crucibles, muffles, sheets, etc. This is effected by blowing the soft block under pressure in a detachable iron mould. Owing to the shape of the quartz block, it is very difficult to produce articles of uniform thickness. Many objects such as pyrometer tubes and laboratory utensils can only be formed in the oxyhydrogen flame.

FROM MANGANESE TO SELENIUM.—J. E. Adams (*Glass Ind.*, **3,** 219, 1922). The procedure for changing a tank of glass is described.

MODERN GLASS FACTORY EQUIPMENT.—W. S. Mayers (*Glass Ind.*, **3,** 221, 1922). Air compressors, blowers, and raw materials storage bins are discussed.

BEAD MAKING AT MURANO AND VENICE.—B. H. Carroll (*Glass Ind.*, **3,** 224, 1922). A detailed account of the industry taken from the U.S. Commerce Reports.

MODERN METHODS OF MAKING PLATE GLASS ILLUSTRATED.—(*Glass Ind.*, **3,** 226, 1922). A series of interior views in the Allegheny Plate Glass Company's Plant.

THE BRITISH SCIENTIFIC GLASS INDUSTRY.—(*Nature*, **110,** 833, 1922). A discussion of the review by W. E. S. Turner. The beginnings of the industry in the United Kingdom are contrasted with the early operations at Jena.

THE APPLICATION OF CALORIZING TO GLASS-MAKING PROCESSES.—S. F. Cox (*Glass Ind.*, **3,** 243, 1922). Calorising is defined as: a heat treatment, in which aluminium is driven into iron or steel, so that on exposure to heat, a protective coat of aluminium oxide is formed. The

application of the process to different parts of glass-making apparatus is discussed.

THE GLASS INDUSTRY OF CHILE.—R. S. Smith (*Glass Ind.*, **3**, 257, 1922).

A STUDY OF THE CONDUCTION PROCESS IN ORDINARY SODA–LIME GLASS.—C. A. Kraus and E. H. Darby (*J. Amer. Chem. Soc.*, **44**, 2,783, 1922). The work of earlier investigators on the nature of the conduction process is briefly discussed, and it is pointed out that insufficient information is supplied by them regarding the condition of the sodium present in glass. Experiments were, therefore, carried out to determine to what extent the sodium is subject to the action of the electric current. The problem was attacked by replacing the sodium by another metal, the depth of whose penetration into the glass could be measured.

THE POTENTIAL DIFFERENCE BETWEEN GLASS AND ELECTROLYTES IN CONTACT WITH GLASS.—W. S. Hughes (*J. Amer. Chem., Soc.*, **44**, 2,860, 1922).

NOTES ON GLASS MANUFACTURE.—C. S. Fox (*Bull. Indian Industries and Labour*, No. 29, Calcutta, 1922). The pamphlet (72 pp.) gives a general survey of the glass industry, with special reference to Indian conditions. It contains sections on : early history, definitions, "flow sheet," raw materials, preparation of batch, furnaces, manufacture of different types of glassware, annealing, finishing, selection of sites for glassworks in India, practical considerations in designs and management. Commercial information (prices, etc.) is given in appendices.

CAPITAL AND WORKING CHARGES OF A QUARTZ MELTING PLANT.—W. Schuen (*Tonind. Ztg.*, **47**, 92, 1923). Prices are quoted at the pre-war rate for a plant with four furnaces.

THE GERMAN SOCIETY OF GLASS TECHNOLOGY.—Fr. Spate (*Sprech.*, **55**, 485, 1922 ; *Glass Ind.*, **4**, 16, 1923). The formation of a new Society with the above title is announced and the form which its future activities will probably take is indicated.

TEMPERATURE CONTROL IN GLASS-MELTING FURNACES.—(*Sprech.*, **56**, 102, 1923). An arrangement for registering the temperature at 7 different points in a tank furnace is represented diagrammatically and described in some detail. By the application of the method outlined, a saving of 10% of fuel was effected on a works which had already been equipped with modern appliances ; and the cost of working the scheme of temp. control amounted to 2% of the expenses on fuel.

THE DEVELOPMENT OF THE GERMAN BOTTLE INDUSTRY SINCE 1900.—F. Hillmann (*Sprech.*, **56**, 56, 1923). A good account is given.

COLOURING GLASS WITH NICKEL.—Kitsuzo Funa (*J. Jap. Cer. Ass.*, 361, 430, 1922). Numerous batches were melted to find the colouring action of nickel and its compounds on various glasses, with or without the addition of oxidising or reducing agents. The conclusions are : (1) Nickel oxide gives a purple colour to potash glasses and a dull brown to soda glasses, though these effects become less distinct as the amount of nickel oxide increases ; (2) varying the bivalent metal of a glass-formula does not affect the colour materially, except barium, which has a peculiar effect on the colour produced by nickel oxide ; (3) in boro-silicate glasses, nickel oxide produces a pinkish purple ; (4) metallic nickel, or nickel carbonate, may be used instead of nickel oxide ; (5) the presence of an oxidising agent (potassium nitrate), a reducing agent (potassium tartrate) or arsenious acid in batches does not affect the colour given by nickel oxide. S. KONDO.

STUDY OF GLASS—REPORT NO. 3.—Kiyohiko Hagiwara, Kan-ichi Morimoto, Kiyoshi Ueda and Taitaro Hiraoka (*J. Jap. Cer. Ass.*, 362, 457, 1922). This paper is a continuation of Report No. 1 in which the authors

attributed the cause of dimness of mirrors to minute spots on the surface of glass. (1) Exudation at high temperatures. When a piece of window-glass was heated to 350°–600°C. for 1—2 hours in an electric furnace, it became covered with minute particles which increased in number with the time of heating. They grew rapidly at 650° and disappeared almost completely when the glass was heated to temp. over 800°. It was observed that their amounts diminished on repeating the process, if they are wiped off every time, and also that their growth ceases completely, or nearly so, after the minute particles have once been erased with a piece of wood or steel. (2) Exudation at ordinary temperatures. Similar minute particles appear also at ordinary temp., though it requires a much longer time, usually more than three days. They must not be confused with the products of weathering. They grow uniformly scattered, in dendritic crystals or groups, the latter two aggregates being probably caused by the atmospheric moisture. (3) The nature of the exuded substance. The substances exuded at ordinary or higher temperatures are hygroscopic and form hydrated crystals. Microscopic examination of these substances, before and after treating with hydrochloric acid or calcium chloride, indicated that they are mainly sodium silicate, sometimes containing sodium sulphate. (4) Amount of the exudation. The amounts of the substances exuded from window-glass when new specimens were heated at 480°–520°C. in a muffle-furnace for 1, 5 and 10 days, were 0·0035%, 0·0052% and 0·0088% of glass respectively. (5) Exudation on the surface of glass-cylinders. Experience in the cylinder-process of manufacturing window-glass tells us that the drawn cylinder is sometimes covered with minute particles, though it happens only rarely. Some cylinders, which broke in drawing, have shown striped growth of the particles, which is more common with window-glass made by the Fourcault or Colburn process. Such a glass is very brittle and breaks usually in the lehr. The authors believe that the minute particles are exuded from glass owing to its unstable state of equilibrium. (6) Exudation in pores. Some pores in glass have much exudation, while others show it only after heating at a temperature over 400°. (7) Mirror glass. Glass for good mirrors must be polished to remove the exudation baked on its surface or must be examined with the vitroscope before it is silvered. S. KONDO.

PATENTS.

PROCESS OF MANUFACTURING OPTICAL GLASSES.—Genzo Shimazu (*Jap. Pat.* No. 43,203, Aug. 1, 1922). Oxides of lead are prepared by oxidising lead-powder by means of natural oxidation or other methods without melting. They are used to make batches for optical glass together with quartz, sodium carbonate, lime and the other usual raw materials. S. KONDO.

DRAWING GLASS SHEETS.—E. C. R. Marks (*Pat. J.*, 1,779, 1923). No. 191,097, Aug. 3, 1921. The molten glass flows directly and continuously from the main supply over the surface of a slab to form a shallow pool, from which the glass is subjected to a drawing stress while it is unsupported at the discharge end of the slab.

MAKING ROLLED GLASS.—Chance Bros. & Co. and A. L. Foster (*Pat. J.*, 1,779, 1923), No. 191,267, Dec. 17, 1921. Description of a method, in which the glass sheets, while in transit between the rolling machine and the lehr, are passed into a tunnel and maintained at a temp. sufficiently high to keep them intact.

MELTING POTS FOR GLASS.—W. H. Squires (*Pat. J.*, 1,780, 1923), No. 191,301, Feb. 8, 1922. The pots have circular, polygonal, or elliptical walls, which may be plane or convex, united by a circumferential portion, part of which rests on the furnace floor.

IMPROVEMENT IN BORO-SILICATE GLASS.—Kitsuzo Fuha (*Jap. Pat.* No. 42,161, March 31, 1922). The new glass has the following composition: Silica 66·0–67·5%, alumina 1·0–1·75%, soda 7·0–8·0% and boric anhydride 22·0–24·0%. The glass adheres more firmly to tungsten-wire, resists more

sudden changes of temp. and resists weathering better than the already-known boro-silicate glasses. S. KONDO.

RESISTANCE GLASS.—V. Horák (*Pat. J.*, 1,785, 1923). No. 192,713. A glass which has a low coefficient of expansion, a high fusing point, and great resistance to chemical action is made from a batch containing: 60–70% silica, 15–30% boric oxide, 1-2% potassium carbonate, 3–6% sodium carbonate, 2–6% kaolin, up to 4% mica, and 1–3% of an oxide of the silicon group, *e.g.*, zirconium or titanium.

GLASS TUBE MACHINE.—Brit. Thomson-Houston Co. (*Pat. J.*, 1,785, 1923.) No. 192,844. An apparatus for severing glass tubes is described.

DRAWING GLASS.—Pittsburg Plate Glass Co. (*Pat. J.*, 1,785, 1923). No. 192,848. Apparatus is described for drawing glass in flat sheets.

COLOURING GLASS.—Corning Glass Works (*Pat. J.*, 1785, 1923). No. 192,919. Colours due to metallic salts in glasses (cobalt or nickel oxide), are modified by addition of substances containing one or more of the halogens; *e.g.*, when potassium chloride is added to the batch of glass containing a very high proportion of boric oxide and coloured with cobalt oxide, the resultant glass has a green instead of a red colour.

GLASS STIRRERS.—C. A. Parsons (*Pat. J.*, 1,782, 1923). No. 191,842, Oct. 22, 1921. A description is given of a stirrer for use in the manufacture of optical glass. It is provided with means for giving a rapid rotary motion, with or without a relatively slow orbital motion. The clay stirrer is of the usual cylindrical type, but is provided with projections, or paddles.

FORMING PLATE GLASS.—Pittsburg Plate Glass Co. (*Pat. J.*, 1,783, 1923). No. 192,092, Jan. 23, 1923. Apparatus is described for forming plate or sheet glass. The molten glass is caused to flow by gravity from the tank through the space between cooled, rotated rolls, whereby the glass is rolled into a sheet.

GLASSWARE-FORMING MACHINE.—Owens Bottle Co. (*Pat. J.*, 1,784, 1923). No. 192,347, Mar. 16, 1922. A machine is described, which has devices for closing the charge opening in the top of each of the parison moulds, means for inverting the latter before they are opened, and also for re-inverting them independently of the ring moulds.

MACHINE FOR DRAWING SHEET GLASS.—E. C. R. Marks (*Pat. J.*, 1,784, 1923). No. 192,427, Aug. 3, 1921.

GLASS-WORKING MACHINE.—Brit. Thomson-Houston Co. (*Pat. J.*, 1,784, 1923). No. 192,508, Nov. 8, 1921. Relates to an automatic machine for making short lengths of flanged tubing, etc.

BOTTLE-BLOWING MACHINE.—Obear-Nester Glass Co. (*Pat. J.* 1,786, 1923). No. 193,080, Sept. 12, 1921.

GLASS-BLOWING MACHINE.—Obear-Nester Glass Co. (*Pat. J.*, 1,787, 1923). No. 193,365, Sept. 12, 1921. Relates to transfer mechanism.

OIL-FIRED POT FURNACES.—Dowell & Sons, & R. S. Dowell (*Pat. J.*, 1,787, 1923). No. 193,482, Nov. 22, 1921. One or more oil burners are arranged to deliver horizontally into a longitudinal tunnel beneath the pots, apertures being provided in the walls of the tunnel to facilitate the removal of broken pots, split metal, etc.

GLASS MOULDS.—E. A. Hailwood (*Pat. J.*, 1,787, 1923). No. 193,536, Dec. 2, 1921. Moulds made by rolling up or forging "rustless" steel or iron are used for producing ware of a finer finish than that obtained with cast moulds.

MANUFACTURE OF SPECIAL GLASS RECEPTACLES.—Brit. Thomson-Houston Co. (*Pat. J.*, 1,787, 1923). No. 193,581, Dec. 19, 1921. Apparatus is described for making receptacles such as X-ray bulbs having windows differing in thickness, composition, or other respects from the main receptacle.

FREEING MOLTEN SILICA FROM AIR.—Brit. Thomson-Houston Co. (*Pat. J.*, 1,780, 1923), No. 191,463, Oct. 11, 1921. The method consists in extruding the silica under pressure through a narrow slit. The furnace is so arranged that the fusion can be carried out under reduced pressure.

GLASS TUBES.—British Thomson-Houston Co. (*Pat. J.*, 1,769, 1922), No. 187,374, Aug. 13, 1921. The invention consists of a machine for producing glass tubes with a contraction suitable for use as an exhaust tube for an electric lamp.

DELIVERING UNIFORM CHARGES OF MOLTEN GLASS.—C. R. Lott (*Pat. J.*, 1,770, 1922), No. 187,661, June 23, 1921. The metal flows from a tank through a tube into a receptacle and thence through a hole in the bottom. The flow from the tube is regulated by a flap valve and from the hole in the receptacle by a reciprocating valve.

PNEUMATIC BLOWPIPE.—V. Lorentz (*Pat. J.*, 1,770, 1922), No. 187,839, Oct. 21, 1921. See Abstract, p. 28.

MAKING GLASS CUPS.—E. A. Hailwood (*Pat. J.*, 1 771, 1922), No. 188,102, Aug. 20, 1921. Description of a press for making glass cups, etc., in which means may be provided for revolving the plunge in order to polish the article.

TRANSPARENT SILICA GLASS.—Brit. Thomson-Houston Co. (*Pat. J.*, 1,772, 1922), No. 188,451, Sept. 14, 1921. The method of making consists in fusing silica in a vacuum and then compressing the fused mass while plastic to reduce enclosed bubbles. The furnace is described.

MANUFACTURING OPTICAL GLASS.—Sir C. A. Parsons, C. J. Peddle and H. M. Duncan (*Pat. J.*, 1,773, 1923), No. 188,721, July 15, 1921. The glass is allowed to cool in the pot, and while it is still viscous, but able to retain its shape without support, it is separated from the pot, thus leaving an isolated mass of glass.

COATING GLASS.—J. W. Martin (*Pat. J.*, 1,773, 1923), No. 188,904, Oct. 20, 1921. A method of coating glass tiles with Keene's or other cement, etc., is described.

DELIVERING UNIFORM CHARGES.—D. A. Ripley (*Pat. J.*, 1,774, 1923), No. 189,168, June 27, 1921. Relates to apparatus for delivering uniform charges of molten glass to moulding machines, etc.

DRAWING GLASS SHEETS.—E. C. K. Marks (*Pat. J.*, 1,775, 1923). Nos. 189,493—6, Aug. 3, 1921. Various forms of apparatus are described.

ETCHING GLASS.—Naamlooze Vennootschap Philip's Gloeilampenfabricken (*Pat. J.*, 1,775, 1923), No. 189,763, Nov. 8, 1922. To produce transparent markings on frosted glass (trade marks, etc.), the design is stamped on in an acid-resist ("Lanoline," bees-wax and resin, with or without resin oil and horse fat), the glass being then etched.

REMOVING GLASS ARTICLES FROM MOULDS.—R. F. Hall (*Pat. J.*, 1,775, 1923), No. 189,818, June 7, 1921. A device is described for ejecting or facilitating the removal of articles from the moulds of a forming machine. Means are provided for holding the glass while the halves of the mould are being opened, and for giving the article a slight push to disengage it.

SHAPING SILICA GLASS.—Brit. Thomson-Houston Co., Ltd. (*Pat. J.*, 1,776, 1923), No. 189,926, Oct. 6, 1921. The silica is fused in a vacuum and then cooled to a congealing temperature. It is then transferred to a heating space under atmospheric pressure, reheated to a plastic state, and then moulded as desired or extruded under pressure through a die.

GLASS BLOWING.—Obear-Nester Glass Co. (*Pat. J.*, 1,776, 1923), No. 190,224/5, Sept. 12, 1921. A description of pneumatically-operated take-out mechanism for glass blowing machines.

MANUFACTURING FUSED SILICA.—H. O. Barnard and H. George (*Pat. J.*, 1,777, 1923), Dec. 8, 1922, No. 190,476. Fused silica, transparent

and free from bubbles, is produced by agglomerating the powdered raw material with gelatinous silica and then compressing it into moulds at a pressure of about 200 kg. per sq. cm. The moulded mass is then heated to 150°C. to remove moisture and is then fused in an electric furnace. Agglomeration is facilitated by first transforming the raw material into crystobalite by heating to about 1,500°C. No. 190,477. A second method consists in melting compact siliceous rocks of a high degree of purity and preferably containing no micro-crystalline cement. The rock is cut into cylinders which are perforated axially so that they can be fitted over the carbon electrode.

GLASS FEEDING-DEVICE.—C. K. Lott (*Pat. J.*, 1,778, 1923), No. 190,737, June 23, 1921. A feeding-device for delivering gathers of glass comprises a furnace with a valve-controlled passage leading to a closed cup or container provided with a discharge orifice. Means are provided for regulating the flow of glass through the orifice by subjecting the container alternately to suction and compression.

GLASS MOULDING.—C. R. Lott (*Pat. J.*, 1,778, 1923), No. 190,986/7, June 23, 1921. The flowing stream of metal is cut into gathers by shears, and a reheating device is provided for directing a flame upwards against the freshly-cut end of the stream. As the moulds move into and out of position below the stream, they move the reheating-device away from or toward the stream. A forming-machine may be used in conjunction with an automatic feeding-device, and is provided with means, mounted on or carried by the mould supports, for positioning each mould in turn beneath the delivery orifice of the feeding-device.

GLASS-BLOWING MACHINE.—Wilzin Automatic Bottle-making Machine Co. (*Pat. J.*, 1,778, 1923), No. 191,012, Dec. 7, 1922. A machine for blowing glassware, particularly bottles, is described.

VI.—CEMENT, CONCRETE, MORTARS, ETC.

ESTRICH GYPSUM.—M. v. Glasenapp (*Tonind. Ztg.*, **47**, 91, 1923). Portland cement saturated with lime was subjected to a high temp. (m.p. of platinum), and on the basis of observations therefrom, it is concluded that estrich gypsum consists of (1) a vitrified, crystalline, optically anisotropic, granular anhydrous calcium sulphate (anhydrite), and (2) from 3 to 5% of a dense amorphous, optically isotropic modification of calcium oxide, both of which are formed only at temperatures above 900°.

MANUFACTURE OF CONCRETE.—F. Wood (*Quarry*, **28**, 38, 1923). The subject is reviewed with particular reference to road structure.

FRACTURES IN CONCRETE ROADWAY CONSTRUCTION.—H. Bentham (*Quarry*, **28**, 43, 1923).

SPECIAL HIGH ALUMINA CEMENTS.—(*Concrete*, **21**, 181, 1922). A résumé is given of the various discussions on the new French cements. These are slow-setting and quick-hardening.

"ELECTRIC CEMENTS."—H. J. Harms (*Concrete*, **21**, 183, 1922). The work of Bied and Magny is recapitulated.

THE NEED OF REVISION OF THE CEMENT STANDARDS.—M. Gary (*Mitt Materialprüfungsamt, Berlin*, **40**, 33, 1922). The author refers to his earlier suggestion, viz.: that the so-called "sand strength" of a cement should be determined. The best cement is one which requires the largest quantity of sand to produce a given strength. Other problems discussed include constancy of volume, grinding (degree of fineness), properties of sand, etc.

COLOURING CEMENT GOODS.—C. R. Platzmann (*Tonind. Ztg.*, **47**, 62, 1923.)

TESTS ON MOULDING OF CONCRETE UNDER PRESSURE.—H. M. Nelson (*Eng. News Record,* **89,** 21, 1922).

CEMENT CONCRETE.—F. Wood (*Quarry,* **28,** 12, 1923). It is pointed out that there is room for a closer study of concrete with regard to (*a*) the mixing of the cement and aggregate; (*b*) the grading of the aggregate; and (*c*) the pressure that is applied to the concrete before or while it is set into position. The process of manufacture of concrete pipes as applied by the Stanton Ironworks Co. is outlined in some detail.

THE EQUIPMENT OF A MODERN CEMENT WORKS.—G. V. Maxted (*Quarry,* **28,** 15, 1923). A detailed description is given of the works of the Humber Portland Cement Co.

DUST COLLECTING ON CRUSHING PLANTS.—W. G. Clark (*Cement Eng. News,* **34,** No. 10, 28, 1922). It is suggested that much of the fine product now wasted might be utilized and sold for agricultural purposes. At the same time the sanitary condition of the plant would be improved.

AUTOMATIC BLOCK MACHINE.—(*Cement Eng. News,* **34,** No. 10, 29, 1922). Description, with illustration of a machine sold by the Kent Machine Co., Ohio.

THE ITALIAN CEMENT INDUSTRY.—(*Tonind. Ztg.,* **46,** 1,153, 1922).

"ASPHALTIC SLAG" AND "ASPHALTIC LIMESTONE."—(*Quarry,* **27,** 395, 1922). A description of improved types of road-surfacing materials, manufactured by W. Sheppard & Sons, Ltd.

GERMAN IRON CEMENT.—(*Allg. Tonind. Ztg.,* **41,** No. 50, 5, 1922). Iron cement has the property of uniting firmly with iron and is completely resistant to heat, cold, moisture, shocks, etc. After setting it can be filed like iron, from which it can scarcely be distinguished. It is able to withstand a pressure of 18 atmospheres. Its various uses are outlined.

WHAT QUALITY OF CONCRETE BLOCK SHOULD BECOME STANDARD?—J. C. Pearson (*Concrete,* **21,** 135, 1922). A specification is recommended, which shall be based on graded requirements as to compressive strength, and shall contain an absorption limit not restricting such units as have been shown by experience to be satisfactory.

TESTS OF CONCRETE IN SEA WATER.—L. C. Wason (*Concrete,* **21,** 151, 1922). Tests are described, from which it is concluded that, if rich concrete is made from good cement, is of normal composition or low in alumina and is thoroughly mixed, with 9 or 10% water,—assuming careful workmanship to produce a dense surface, etc.—it should prove durable in sea water, provided it is not subjected to excessive abrasion.

AUTOMATIC VERTICAL KILNS FOR BURNING CEMENTS.—E. Candlot (*Chim. Ind.,* **8,** 402 T, 1922). The advantages of the Perpignani-Candlot kiln (described and illustrated), are pointed out. This kiln is likely to be used to an increasing extent in the future wherever the dry process is applied. It costs less to instal than the rotary type, absorbs no more labour, operates mechanically, and requires only 0·4 of the motive power, and 0·5 to 0·7 of the fuel, consumed by the latter type. The rotary kiln will be used, however, where the dry method is inapplicable.

WATERPROOF CEMENT; "KYNASITE."—(*Chem. Age,* **8,** 238, 1923). Tests carried out by F. E. Drury showed definitely that Kynasite, when used to replace a portion of the sand in cements and mortars, is an effective waterproofer, the imperviousness being increased by raising the proportion added.

DETERIORATION OF STORED CEMENT.—(*Can. Chem. Met.,* **7,** 12, 1923). An extract from Serial 2,377 of the Bureau of Mines. Deterioration of cement stored in bulk is less pronounced than when put into bags, owing to the smaller surface exposed.

CONCRETE; THE INFLUENCE OF CONSTRUCTION ON MAINTENANCE.—"Amiens" (*Gas World,* **78,** 205, 1923). In a discussion of the possible

applications of concrete for structural purposes on gas works, the writer calls attention to the precautions which must be observed in the preliminary erection of a structure in order to eliminate the problem of maintenance and repair as far as possible, and also indicates the means for quickly and effectively carrying out repair work, where this may have become necessary.

ORNAMENTAL CONCRETE IN INDIA.—C. C. Dangoria (*Concrete*, **21**, 134, 1922). Five photographic views illustrate the manner in which concrete can be made to serve artistic purposes.

TESTING LIME AND CEMENT COLOURS.—C. R. Platzmann (*Tonind. Ztg.*, **47**, 185, 1923). The following methods of testing are discussed: (1) physical; (2) chemical, and (3) analytical.

ON THE CRUSHING STRENGTH OF CONCRETE.—(*Tonind. Ztg.*, **47**, 99, 1923). A general review of current literature on the subject.

PLASTER OF PARIS.—A. Brittain & C. Elliott (*J. Soc. Chem. Ind.*, **42**, 154 T., 1923). In general, the properties of a plaster depend upon the method of manufacture, the temperature, and the time of calcination. The state of subdivision affects the setting time and the tensile strength. The former is accelerated, and the latter increased by an increase in the fineness of the particles. Re-grinding after calcination gives a stronger material and an accelerated set. Gypsum acts as an accelerating agent, but decreases the tensile strength; any excess over the usual 2–3% must be regarded as an impurity, which reduces the quality of the plaster. The setting is retarded by slow-setting anhydrite, which is the cause of the longer setting time of plaster made at moderately high temperatures. Dead burnt plaster and natural anhydrite act as inert impurities, reducing tensile strength. Increase in the amount of water used in gauging has the effect of lengthening the setting time and decreasing the tensile strength. Variations in the temperature of the gauging water cause variations in the setting time and tensile strength.

Patents.

CONCRETE.—A. J. Myles (*Pat. J.*, 1,778, 1923). No. 190,849, Oct. 27, 1921. A mixture of Portland cement and a light porous aggregate such as sawdust or cork dust, with or without fillers, such as barytes and chalk, and colouring matter, *e.g.*, iron oxide, is gauged with a solution of a soluble salt such as calcium chloride.

MOULDING CONCRETE PIPES, ETC.—N. F. Spence (*Pat. J.*, 1,779, 1923), No. 191,156, Oct. 6, 1921. A centrifugal machine is described.

HARDENING CONCRETE.—O. Roneka (*Pat. J.*, 1,779, 1923), No. 191,243, Nov. 25, 1921. Cement or concrete articles are heated in a closed vessel at the rate of 1–5°C. per minute to a temp. of 60–80°, small quantities of steam being admitted. The heating is then continued at the rate of 0·1–1°C. per minute by the admission of steam, either alone or acting in conjunction with external heating means, until a pressure of 7–13 atmospheres is attained.

MOULDING CONCRETE PIPES.—Scott & Son (*Pat. J.*, 1,782, 1923), No. 192,035, Sept. 19, 1922. A machine is described, in which the concrete is distributed on the walls of the mould by centrifugal force due to rotation about a vertical axis.

MOULDING CONCRETE.—M. W. Harvey (*Pat. J.*, 1,770, 1922), No. 187,754, Aug. 15, 1921. Relates to machine with an intermittingly rotated table.

TAMPING CONCRETE.—F. T. Gray and Whittaker, Ltd. (*Pat. J.*, 1,770, 1922), No. 187,862, Nov. 17, 1921. Description of tamping apparatus mounted on a frame.

MOULDING CONCRETE PIPES.—W. H. Sonley (*Pat. J.*, 1,770, 1922), No. 187,867, Nov. 22, 1921. Relates to centrifugal moulding machines.

CONCRETE BLOCK PRESSES.—F. E. Watkin and C. H. Hill (*Pat. J.*, 1,773, 1922), No. 188,905, Oct. 20, 1921.

CONCRETE.—C. A. Jagaer (*Pat. J.*, 1,775, 1923), No. 189,745, July 31, 1922. Portland cement is mixed in predetermined proportions with sand which has been washed and kiln-dried, and the mixture is stored in moisture-proof containers.

ARTIFICIAL STONE, CEMENTS, ETC.—H. Berry (*Pat. J.*, 1,776, 1923), No. 189,892, Sept. 13, 1921. Waste slate, coal shale, granite, broken bricks, clinker, slag, or any aluminium silicate, or sand, quartz, flint or other form of silica, is powdered and mixed with magnesium oxide, and with either tartaric acid or the carbonates, hydrates, or bicarbonates of sodium, potassium or ammonium.

TREATING STONE WARES.—Yuichi Shinagawa and Seizabura Yoshizaka (*Jap. Pat.* No. 43,361, Aug. 29, 1922). Engraved wares of stone are heated in access of air after they have been coated with an oil. The treatment makes their texture more distinct or changes their color, and increases their hardness. S. KONDO.

PROCESS OF MANUFACTURING PLASTER OF PARIS.—Seikichi Fukuzawa, Ito Fukuzawa and Toyo Gips Co. (*Jap. Pat.* No. 43,679, Oct. 11, 1922). The product of chemical reaction between sulphuric acid and lime is left in heaps until the grains assume spheroidal shape. They are then washed with water to get rid of magnesium sulphate. They are again left in heaps until they assume spheroidal shape, and are finally used in the manufacture of plaster of Paris. S. KONDO.

PROCESS OF BURNING PULVERIZED FUEL IN WHICH PORTLAND CEMENT IS OBTAINED AS BY-PRODUCT.—Tsuneichi Fujiyama (*Jap. Pat.* No. 43,420, Sept. 8, 1922). Lime and small amounts of quartz or other similar substances are mixed with pulverized fuel in such proportions that they compose Portland cement with the ashes of the fuel. The pulverized mixture is burned with air-blast to heat boilers or other apparatus and to produce cement-clinker at the same time. S. KONDO.

MARBLE-CEMENT.—Kihichi Nakamura. (*Jap. Pat.* No. 43,347, Aug. 28, 1922). Pieces of glass or pattern-plates of various shapes are scattered on a base-plate which has previously been coated with celluloid or glue and has a frame on it. A coloured mortar composed of sodium silicate, Portland cement, colouring matter and water is poured on the plate as thick as the glass-pieces or the pattern-plates. They are then picked out and similar mortar or different colour is poured in their places. Then cracks are formed in the mortar by inserting a spatula into the surface of the film and moving it in places. The cracks are now filled with similar mortar of another colour. The artificial stone thus obtained is soaked in a solution of sodium silicate and is then polished. Marble, granite and other natural rocks can be imitated by this process. S. KONDO.

PROCESS OF MANUFACTURING PAVING MATERIAL.—Komakichi Kato and Chiaki Kamibayashi (*Jap. Pat.* No. 42,701, May 30, 1922). Ground Soja beans are treated with a solution of an alkali. Any soluble aluminium salt and coal-dust are added to the product. The mixture, together with cement, lime, sand, etc., is used in paving. S. KONDO.

MATERIAL FOR ARTIFICIAL STONE.—Toyoji Hatanaka (*Jap. Pat.* No. 42,502, May 8, 1922.) A white powder consisting of magnesia, zinc oxide, ground glass or other mineral substance, white Portland cement and clay, and a solution of magnesium chloride, Gloiopeltis furcata (a kind of glue) and alum in water, are used in making artificial stone. Magnesium chloride is sometimes excluded from the solution. S. KONDO.

PAINT FOR WATER-PROOFING CEMENT.—Nakajiro Mano and Ryujiro Yanaka (*Jap. Pat.* No. 42,350, April 18, 1922). Fatty acid and solid paraffin are dissolved in naphtha of low melting point. S. KONDO.

PITCH-CEMENT.—Ichita Kishi (*Jap. Pat.* No. 42,291, April 12, 1922). Relates to a pitch-cement which is prepared by melting a mixture of

petroleum, pitch, coal, brown coal or peat and magnesia. S. KONDO.

VIII.—HISTORICAL, EDUCATIONAL INSTITUTIONS, ETC.

THE LATEST LITERATURE ON THE "LEAD QUESTION."—P. Bartel (*Ber. D. K. Ges.*, **3**, 86, 1922). A comprehensive review of the literature dealing with lead poisoning is given, the subject being treated under the following heads: (1) Government rules and regulations (*a*) in Germany, (*b*) in other countries; (2) papers and discussions at meetings, congresses, or in parliaments (*a*) in Germany, (*b*) in other countries.

ART AND ITS APPLICATION TO THE POTTING INDUSTRY.—J. Burton (*Pot. Gaz.*, **48**, 106, 1923.

THE MEANING OF THE WORD CERAMIC.—H. Hecht (*Ker. Rund.*, **31**, 1, 1923). The writer disagrees with the American proposal to include glass, cement, lime, plaster, etc., under the term ceramic, which should be limited to those products which are first formed out of clay, or clay-containing bodies, and then fired with or without glaze.

VASES FROM THE LUXOR TOMB.—(*Pot. Gaz.*, **48**, 463, 1923).

THE STORY OF CLAY.—H. J. C. Johnston (*Pot. Gaz.*, **48**, 458, 1923).

THE HISTORY OF CHINESE PORCELAIN.—(*Pot. Gaz.*, **47**, 1,847, 1922). An abstract of a paper appearing in the Bulletin of the Boston Museum of Fine Arts.

THE LARGEST POTTERY IN THE WORLD.—(*Brick*, **61**, 880, 1922). An account of the development of the Homer Laughlin China Co., of Newell, W.Va. The plant has a total of 62 kilns, and is said to be 2½ times larger than any other.

CHELSEA PORCELAIN.—W. Burton (*Nature*, **110**, 871, 1922; *Brick Pot. Tr. J.*, **31**, 13, 1923). A review of the book by W. King.

BRICK MANUFACTURE IN CHINA.—(*Allg. Tonind. Ztg.*, **41**, No. 50, 4, 1922). A short account, taken from a report by A. T. van Wiyngaarden, published in the Dutch journal *Klei*.

ON THE ORIGIN OF GLAZED BRICKS IN THE MIDDLE AGES.—Hasak (*Allg. Tonind. Ztg.*, **41**, No. 51, 1922).

ENGLISH SALT-GLAZE STONEWARE.—(*Brit. Claywr.*, **31**, 297, 1922). A review, with illustrations, of J. F. Blackie's book: "The A B C of English Salt-glazed Stoneware."

Abstracts.

I.—RAW MATERIALS.

GENERAL.

BENTONITE.—(*Chem. Age*, **8**, *China Rev., Sect.*, 11, Feb., 1923). The analyses of five selections of Bentonite, found in N. America, are given. The SiO_2-content varies between 59·84 and 69·52%, and the Al_2O_3-content between 11·84 and 26·58%.

CHINA CLAY.—H. F. Collins (*J. Soc. Chem. Ind.*, **42**, 88, 1923). A general account is given of the composition, preparation and uses of china clay.

TITANIUM: ITS USES, PROPERTIES, AND SOURCES OF SUPPLY.—R. J. Anderson. (*Chem. Age*, **8**, 331, 1923).

TILE- AND BRICK-MAKING MATERIALS OF NIGERIA.—(*Bull. Imp. Inst.*, **20**, 302, 1922). Specimens of *Old Clay*, *New Clay*, and *Tiles* were sent to the Imperial Institute for testing purposes. The *Old Clay* was a hard, buff-coloured clay, containing fragments of quartz, iron and felspar. The *New Clay* was a soft, light buff-coloured clay, containing a large amount of quartz and iron oxide fragments, together with vegetable matter. The results of tests showed that the "Old" clay could be used either alone or mixed with grog or "New" clay for making bricks. Grinding or washing would be necessary for tile making. The "New" clay lacks binding properties, and a certain proportion of "Old" clay would have to be added in brick manufacture. For tiles, 2% of Portland cement may be added to the "New" clay, or it may be washed and mixed with grog.

RAW MATERIALS: OCCURRENCE, PREPARATION, ETC.

REFRACTORY CLAYS OF ILLINOIS.—C. W. Parmelee (*J. Amer. Cer. Soc.*, **5**, 685, 1922). The geological occurrence of the fireclay deposits in Illinois is briefly discussed, and the results of testing typical samples from the various areas are given.

CERAMIC DEPOSITS OF SASKATCHEWAN.—(*Chem. News*, **126**, 277, 1923). The clays vary in quality from the lower grades, used in making bricks and tiles, to a kaolin which burns very white.

CHINA CLAY IN CALIFORNIA.—T. Normile (*Brick*, **62**, 979, 1923). The Californian china clay is of excellent quality, and contains 66% SiO_2, 22·8% Al_2O_3, very faint traces of iron, the residue being water. Some of the clays are very plastic, rendering them suitable for making table ware, sanitary ware, and electric porcelain.

OIL FUEL FOR CLAY DRYING.—(*Chem. Age, China Rev. Section*, p. 10, June 16, 1923). An account is given of experiments which have been carried out for over six months with Shell-Mex oil fuel at Great Hallage China Clay Co.'s works at Par, Cornwall. The drying capacity of oil is 156% above that of coal, and it can be handled more economically.

THE ARTIFICIAL PREPARATION OF GRAPHITE.—E. Ryschkewitsch (*Brennstoff-chem.*, **4**, 39, 1923).

THE DRYING OF CHINA CLAY.—(*Chem. Age, China Rev. Sect.*, **8**, 10, Feb., 1923). A new process, invented by T. Rigby, is described. Steam is used as the heating medium through metal surfaces, usually in the form of drums. The steam driven off from the china clay itself is also utilized in a second drying chamber, arranged in a manner similar to the first. The only fresh heat coming into the dryer is that introduced into the drums at the first stage, the remainder of the drying being effected by the steam driven from the clay itself. It is expected that, with a six-stage machine, 50 tons

of clay will be dried per ton of coal; or 30 tons with a four-stage plant. It has been demonstrated successfully that the principles of the invention are sound.

REFRACTORY CLAYS OF TEXAS.—J. H. Kruson (*J. Amer. Cer. Soc.*, **5**, 643, 1922). A brief note on the clay deposits of Texas which might be used for low-grade fireclay products. The chem. analyses give: 70·05–77·75 SiO_2, 11·04–18·8 Al_2O_3, 0·5–3·19 Fe_2O_3, 0·5–0·84 CaO, 0·27–0·38 MgO, 0·29–0·42 K_2O, 0·25–1·12 Na_2O, 1·0—1·31 TiO_2, 3·75–6·70 H_2O.

Patents.

ALUMINA.—A. L. Pedemonte (*Pat. J.*, 1,791, 1923), No. 195,295, May 5, 1922. Pure alumina is obtained from ferruginous bauxite by heating in a reducing atmosphere to render the iron and titanium magnetic, separating these impurities by magnetic action, dissolving the purified bauxite in HCl or H_2SO_4, digesting to render silica and any remaining titanium insoluble, filtering and evaporating the filtrate to dryness and calcining the aluminium salt to obtain alumina and recover the acid.

ALUMINA.—Mr. Buchner (*Pat. J.*, 1,794, 1923). No. 195,998, Oct. 12, 1921. Pure alumina is precipitated by ammonia from the solution obtained by lixiviating aluminous material rendered soluble by fluxing with a bisulphate. The latter is obtained by heating at normal or reduced pressure, in a separate operation, ammonium sulphate, or a double sulphate of ammonium and an alkali metal, and the ammonia evolved is utilized in the subsequent precipitation of alumina.

PHYSICAL AND CHEMICAL PROPERTIES, TESTING, ETC.

INVESTIGATIONS ON CLAY IN THE GREEN CONDITION.—G. Keppeler (*Ber. D. K. Ges.*, **3**, 257, 1922). The development of the electric furnace, and of methods of accurately measuring high temperatures has had the effect of directing the attention of the majority of ceramic investigators to the problems connected with the firing of clay wares, *i.e.*, to the pyrochemistry of clays, with the result that work on clays in the raw, or green state, particularly from the standpoint of mineralogical constitution, has been somewhat neglected. Stremme, in 1908, showed that the colloidal substances in clay, known under various names, *e.g.*, Montmorillonite, Halloysite, Alophane, etc., are not distinct, chemical compounds of definite, stoichiometrical composition, but rather more or less accidental formations of varying composition, though fundamentally of the same nature. He proposed that they should all be included as a class under the name of Allophanoids. Experiments have been conducted in Germany with the object of determining to what extent Allophanoids enter into the composition of the more important clays, since it was recognised that if this point could be settled satisfactorily, an explanation of the difference in the behaviour of kaolins and plastic clays would be forthcoming. Mellor found (*Trans.*, **16**, 74, 1916), that Halloysite was not contained in Glenboig clay, but in addition to the crystalling clay substance kaolinite, he mentions the colloid mineral "clayite." The Allophanoids are characterised by great solubility in HCl and by the varying proportions of alumina, silica and water in their composition. It was therefore assumed that any allophanoids present in a clay would be removed in solution by treatment with HCl. In the experiments, three well-known German plastic clays were used, which were comparatively pure and rich in clay substance; and in order to test the effect of the same treatment on clay substance (*i.e.*, for purposes of comparison), three kaolins were also examined by the same methods. In the case of the clays about 10% went into solution with HCl, and of the kaolins from 5 to 7 per cent. Of the soluble portion no less than $\frac{1}{2}$—$\frac{3}{4}$ consisted of alumina; much iron was also dissolved. The important result was, however, that, in the soluble portion, the molecular ratio of Al_2O_3 to SiO_2 was as 1 : 2, indicating that clay substance

had, in the main, gone into solution. Much more clay substance was, in fact, dissolved than had been expected, and in consequence the test for any allophanoid-content was placed upon a much less secure basis. The results of the tests point to the conclusion that the greater plasticity of the clays is due to the individual particles being more finely divided, giving greater dispersion, rather than to the presence of colloids varying more or less in composition from clay substance. Investigations are being continued and the solubility of plastic clays in HCl is being examined in further detail.

The treatment of clays and kaolins with HCl has the remarkable effect of changing their behaviour considerably. The high content of colloidal silica causes increased plasticity; the hygroscopicity is greatly increased, the fire shrinkage is greater. At temperatures above 1,100°C., the finely divided silica appears to have a fluxing effect.

On heating to moderate temperatures, colloids undergo certain changes, such as loss of water, and increase in the size of the particles. An indication of the colloidal content of a clay can, therefore, be obtained by heating clays to temperatures of about 200–400° and noting changes in hygroscopicity, for instance. It was shown by experiment that, on heating to 400°, the hygroscopicity of the kaolins was reduced from 3·77 to 2·49, that of the clays from 9·34 to 7·12. Above 400° the clay substance itself begins to decompose and give off water. This treatment has already been applied to overcome certain technical difficulties, such as "stickiness" in clays. But it may also be used in preparing clays for *casting purposes*. In casting, the less water required to produce a slip of given fluidity, the larger the quantity of clay suspended in a given volume. As is well known, the addition of a definite quantity of alkali greatly increases the "carrying capacity" of the water in this respect. In the case of Zettlitz kaolin, it has also been found that if, in addition to the alkali, 0·24% of humic acid is added, the dispersion capacity is still further increased. If the kaolin is preheated to 300 or 400°, a slight improvement only is the result. If, however, the latter temperature, at which clay substance begins to decompose, is exceeded, the suspending effect of the alkalies and the humic acid is reduced, showing that the casting qualities of a clay are directly related to the clay substance content. The practical utility of this method of obtaining suitable casting slips is of the greatest importance where thick-walled ware has to be cast. Hitherto, highly plastic clays have been used for this purpose in practice, but these clays react only very slightly to the usual liquifying agents, as is well known to all who have attempted to cast with a typical stoneware clay. A large quantity of water is required to produce the necessary slip consistency, and absorption by the mould is very slow. By preheating such clays, which apparently contain foreign colloidal matter surrounding the clay particles, to 200–400°, these difficulties can to a large extent be overcome. But it is important to note that these preheated clays require, in addition to the alkali, some colloid of a slightly acid reaction, such as silica acid, humic acid, etc. In this way, much more clay can be held in suspension by a given volume of water than would be possible with the clay treated in its original condition. The slip produced in this manner has the normal creamy consistency, although the clay is much shorter after the preheating, and feels almost sandy to the touch. Furthermore, the water is absorbed much more rapidly from these slips. In casting thick-walled objects, as mentioned above, double moulds should be used, or alternatively, a core must be inserted in the mould. The writer claims that this method opens up a new technical process for casting with clays, which hitherto have been found unsuitable for casting thick-walled objects.

THE EFFECT OF ELECTROLYTES ON PLASTIC CLAY.—J. D. Brumbaugh (*Brick*, **62**, 221, 1923). The purpose of the investigation was to determine the effect, if any, of the addition of small percentages of electrolytes to the water used to prepare clay in such a state of "workability" as is used in power moulding machines; and further, to

determine whether or not, by the addition of a small percentage of electrolyte to the water of plasticity, the required state of workability can be produced in the clay by the addition of a smaller quantity of water. The work of previous investigators is briefly reviewed. This is followed by a description of the apparatus used in this investigation. Since the object was to determine the effect of electrolytes on clay, some method of measuring the comparative changes in the workability of the clay had to be developed. For this purpose, two types of plastometers were used, namely, an impact plastometer and a constant pressure plastometer. The latter duplicates, as nearly as possible, the phenomena which take place when clay is forced through the die of an Auger hollow-ware machine. The clay employed in these tests was a typical brick and hollow-ware clay of Ohio, containing 63·62% silica, 21·3% alumina and iron, 1·4% calcium oxide, 0·72% magnesia, and 10·4% water. In discussing the data obtained, it is pointed out that much depends upon the nature of the raw material. Conclusions drawn from the results obtained with any particular clay, do not necessarily apply in detail to other similar types of clay. The results obtained by the investigator with the Ohio clay in question were as follows :—

Hydrochloric acid caused the clay to become more fluid, the degree of fluidity increasing with each increase of acid.

Sodium Chloride caused the clay to become more fluid until 1·5 per cent. had been added, when further additions caused a decrease in fluidity until about 5 per cent. had been added, after which further increase of the electrolyte apparently caused little change.

Ammonium chloride caused the clay to become less fluid until 1·25% had been added, when further addition caused increased fluidity until 1·75% had been added, after which further increase had little effect.

Aluminium chloride reduced fluidity until 0·5% had been added. Further additions up to 3 per cent. increased the fluidity, but beyond this, the electrolyte had little effect.

Sulphuric acid decreased the fluidity until 1 per cent. had been added. With a further increase the clay became rapidly more plastic until 1·5 per cent electrolyte was present. Still further additions up to 2 per cent. rapidly reduced fluidity. A further increase caused little effect.

Barium chloride caused a steady increase in fluidity until 3 per cent. had been added. Further additions lead to a slight decrease in fluidity.

Calcium hydroxide caused a steady increase in the fluidity until 2 per cent. had been added, when further additions reduced fluidity slightly.

From the above results, the electrolytes investigated are divided into four groups :(1) Electrolytes which cause the clay to become more fluid, *e.g.*, hydrochloric acid ; (2) Electrolytes which first increase fluidity, while further additions decrease fluidity (sodium chloride and sodium hydroxide) ; (3) Electrolytes which first reduce fluidity up to a certain limit, beyond which the opposite effect is produced (ammonium chloride, aluminium chloride, sulphuric acid) ; (4) Electrolytes which cause a decrease in fluidity (calcium-hydroxide and barium chloride).

Microscopical study. When the clay was mixed with the standard proportion of water and observed under the microscope, there appeared to be three general classes of constituents : (1) crystalline, (2) amorphous, and (3) colloid particles. The first two appear to remain constant in size, whether the degree of fluidity is increased or decreased, while the colloid particles decrease in size with an increase in fluidity. In the author's opinion, these amorphous, inorganic particles have a submicroscopic porous structure ; they absorb water eagerly and gradually assume the coherent physical state of a gel, which causes the wet mass to assume a plastic state. The decrease in size of these particles is probably due to the added electrolyte undergoing dissociation in the solution, and yielding anions and cations, according to the state of equilibrium. It is further assumed that the anion, particularly the chlorine ion, is more readily absorbed by the ultramicrons than the cation. The anion thus imparts a negative charge to the clay particles, and sub-

division proceeds in a manner very similar to diffusion.

With regard to the second object of the investigation, viz., the possibility of reducing the amount of water required to produce the desired workability, it was found that 1·5% of NaCl reduced the quantity of water required by 17%. But before recommending the use of salt with tempering water, it would, of course, be necessary to investigate its effect on the tensile strength of the dried clay, on the cracking tendency, etc.

THE MICROSCOPICAL EXAMINATION OF CHINA CLAY.—J. M. Coon (*Chem. Age*, **8**, *China Rev. Section*, p. 15, June 16, 1923). Brief extracts from a paper read before the Royal Microscopical Society. The methods of using the microscope and of diagnosing kaolinite, muscovite, mica, quartz, tourmaline, zircon, and topaz are described.

STUDIES ON THE DOLOMITE SYSTEM. PART I. THE NATURE OF DOLOMITE.—A. E. Mitchell (*J. Chem. Soc.*, **123**, 1,055, 1923). Research was undertaken with the object of determining whether dolomite is a compound ($CaCO_3$, $MgCO_3$) or a solid solution of calcite and magnesite. Measurements of the dissociation pressures of calcite, magnesite, and dolomite were made, and it is shown that the three substances yield three different and definite results. It is concluded that the thermal dissociation of dolomite takes place according to the equation $CaCO_3,MgCO_3 \rightleftharpoons CaO, MgO + 2\ CO_2$. The specific heats of magnesite and of the solid decomposition product of dolomite were determined in a simple and fairly accurate apparatus (described) and were found to be 0·2003 and 0·2101 cal. respectively for 15–20°. The heats of solution of dolomite and of its solid decomposition product in HCl were determined, and from these the heats of formation of the two substances from their elements were calculated. It is deduced that the formation of dolomite form magnesite and calcite would involve the absorption of 4·52 kg. cals. per gram-molecule of dolomite. It is concluded that with present knowledge, it is impossible to decide whether dolomite is a singular point in a series of solid solutions or a definite compound.

THE INFLUENCE OF HEAT ON THE MICROSCOPIC PROPERTIES OF SILICA IN ITS DIFFERENT MINERAL FORMS.—J. T. Robson (*J. Amer. Cer. Soc.*, **5**, 670, 1922). A study was made of the effect of heat treatment at cones 13 and 14 on the index of refraction of the four common mineral forms of silica, viz.: sand, quartz, chalcedony and French flint. The results are tabulated as follows :—

Material	Index before heating	Index after heating to cone 13 (1390°C)	Index after heating to cone 14 (1410°C)
Sand	1·545	1·545	1·509
Quartz	1·545	1·545	1·517
Chalcedony	1·540	1·527	1·495
French Flint	1·527	1·487	1·487

The effect of these mineral forms on the index of refraction of porcelain bodies fired to cones 13 and 14 is also given.

ELASTICITY AND SYMMETRY OF QUARTZ AT HIGH TEMPERATURES.—A Perrier and B. de Mandrot (*Comptes rendus*, **175**, 622, 1922). Abstract in *Science Abstracts*, **26a**, 98, 1923.

PROPERTIES OF CHINA CLAY SOLS.—A. B. Searle (*Chem. Age, China Rev. Section*, June 16, p. 8, 1923).

THE DRYING SHRINKAGE OF KAOLINS AND CLAYS.—A. Bigot (*Cer.*, **36**, 55, 1923). The experiments described were conducted on soft pastes of (*a*) kaolin from Eyzies; (*b*) kaolin from Plémet; (*c*) white clay from St. Aignan ; (*d*) Westerwald clay ; (*e*) red Tronquay clay and (*f*) an argillaceous sand from Tronquay. The results are tabulated, and curves are given

correlating the lineal shrinkage and the loss of water on air-drying up to 110°C. Plasticity is figured by dividing the weight of water of plasticity by the total weight of water absorbed and multiplying the result by the shrinkage. The plasticity figures for *a*, *d*, *e* and *f* (above) were 4·25, 4·92, 5·16 and 1·42 respectively.

KAOLINS, CLAYS, BAUXITES, ETC. VOLUME CHANGES UNDER HEAT TREATMENT.—A Bigot (*Cer.*, **26**, 56, 1923). The materials tested included : (*b*) white bauxite (Maussanne), containing no free silica ; (*r*) red bauxite (Brignoles) containing some free silica ; (*k*) Eyzies kaolin, containing no free silica ; (*g*) stoneware clay (Nièvre) containing free silica, and (*s*) a mixture of equal portions of kaolin and silica. Curves are given showing variations in length as a function of temp. It is concluded that : (1) bauxites, kaolins and clays containing no free silica commence to shrink below 1,000°; (2) all clays and bauxites, which commence to expand below 1,000° contain free silica ; (3) if heated rapidly, clays and kaolins blister and swell before the fusion temp. is reached. The bauxites do not present this peculiarity. This swelling is due to the volatilization of silica or silicates, small cavities being formed. The author succeeded in reproducing artificially hard, impermeable pumice stone form certain clays and other silicates. The composition of two such is given and photographs are reproduced.

COMPARATIVE TESTS OF ENGLISH AND AMERICAN WHITINGS.—A. E. Williams and B. J. Woods (*J. Amer. Cer. Soc.*, **5**, 901, 1922). Twenty-two samples of American and English whitings were submitted to examination and tested as follows : (1) visual examination ; (2) microscopical examination ; (3) determination of fineness of grain by (*a*) partial chem. analysis ; (*b*) noting the effect of different whitings on the softening point of ceramic cone mixtures, and (*c*) the effect on the rate of vitrification of porcelain bodies. The results indicate that, although the English whitings contain considerably more fine material of a colloidal nature, the American varieties appear to be sufficiently fine-grained for all ceramic purposes.

THE MECHANICAL MOVEMENT OF WATER THROUGH CERTAIN CLAYS AND ITS CONTROL.—H. G. Schurecht (*J. Amer. Soc.*, **5**, 928, 1922). Experiments were conducted to improve the casting properties of Georgia clays by studying the movement of water through them. It was found that the permeability of the clays to water was independent of the time between 2 and 10 days. The capillary rise of water through the clays may be expressed by the formula : $H=C_h$ (log T—1·041), in which H is the height attained by water in time T, and C_h is approximately constant between 10 and 250 minutes. This factor for Georgia clay is $4{\cdot}66 \pm 0{\cdot}80$, for N. Carolina kaolin $6{\cdot}67 \pm 0{\cdot}30$, and for English china clay $7{\cdot}30 \pm 0{\cdot}70$. The great capillary conductivity of water through primary kaolins explains why bodies containing them dry more rapidly and release from the mould more readily than those containing secondary clays. Methods for improving Georgia clays are discussed.

THE PRODUCTS OF THE CALCINATION OF FLINT AND CHALCEDONY.—E. W. Washburn and L. Navias (*J. Amer. Cer. Soc.*, **5**, 565, 1922). Measurement of the following physical properties was made : specific gravity at 0°, 25° and 98°, the index of refraction, the coefficient of thermal expansion up to 300°, the inversion temperature and volume change on inversion, and the X-Ray spectra. The materials studied were quartz, tridymite, cristobalite, silica glass, and raw and calcined flint and chalcedony. For measuring specific gravity, a special vacuum pyrometer was employed and the immersed powder was later subjected to a pressure of 1,000 atmospheres. The numerical data obtained are tabulated and summarised and the X-Ray spectra are shown. The sp. gr. of calcined chalcedony was raised 2% by fine grinding. It is concluded that all the known facts concerning chalcedony are in harmony with the theory that the raw material is colloidal quartz and the calcined material colloidal cristobalite.

PRACTICAL HINTS ON THE MANUFACTURE OF DOLOMITE EARTHENWARE.—G. Steinbrecht (*Ker. Rund.*, **30**, 471, 1922). The manufacture of dolomite earthenware, as carried out at a few works in South Germany and in Switzerland is described. The raw dolomite of S. Germany, contains about 20 per cent. of clay. The composition of the earthenware body is approximately one-third of each of the three ingredients—raw dolomite, quartz sand and clay. The firing temperature is very low—about cone 03–04, and the shrinkage in the biscuit oven is very slight. The faults usually met with are generally due to improper treatment of the materials. If too finely ground, the body assumes a peculiar consistency which makes it difficult to work up, especially if it has been stored for some time in a very damp place

Storing the body for a sufficient length of time is an important consideration, which frequently does not receive the attention it deserves. Before storing the body, it is preferable to render it thoroughly homogeneous by passing it through pug or beater mills. The body must be kept in a moist condition during storage. For decolorising the slip, the writer is in favour of the use of electro-magnets, but he suggests a series of small receptacles, about 20 in. deep, placed one behind the other in such a way that any one of the series can be shut off. The magnets can then be placed at the overflow of each container. The cobalt salts used to impart the blue colour are partially soluble in water, and to avoid any consequent loss, they may be calcined and ground with chalk, a little china clay being added. This renders them less soluble. Cobalt chloride absorbs moisture and must therefore, be kept in air-tight vessels. Cobalt phosphate (Co_3PO_4) should preferably be first ground with china clay. Cobaltic oxide and cobalto-cobaltic oxide should be thoroughly mixed with china clay and calcined ; a soft, black powder is thus formed which is ground further and then added to the slip.

II.—MANUFACTURING PROCESSES :

GENERAL.

INVESTIGATION OF DUST PRESS PRACTICE AS INFLUENCING FINISHED SIZES AND CRACKING.—H. Spurrier (*J. Amer. Cer. Soc.*, **5**, 798, 1922). Owing to erratic firing behaviour, it was thought advisable to investigate the factors affecting finished sizes of ware. Uneven distribution of air and water and uneven density produced irregular shrinkage with consequent cracking and warping. It is shown that the percentage of water in the clay as pressed is the dominant factor affecting shrinkage. Suitable loading of the die corrected the differential shrinkage. The experimental procedure is outlined, and the influence of the rate of pressing on the porosity is set forth.

THE MANUFACTURE OF POROUS, HOLLOW BRICKS AND TILES.—(*Südd. Tonind.*, **5**, Feb., 1923). The difficulties of the manufacture of this material are pointed out, and the writer details a number of his experiences.

THE LOS ANGELES PRESSED BRICK COMPANY'S PLANT.—(*Brick*, **62**, 940, 1923). An account of the works and methods is given. The illustrations of the plant are numerous and good.

HISTORY OF THE DEVELOPMENT OF SILICON CARBIDE REFRACTORIES.—C. F. Geiger (*J. Amer. Cer. Soc.*, **26**, 301, 1923). An account of the development of carborundum refractories since Acheson took out his first patent in 1893, is given. At present, silicon carbide refractories are produced in the U.S. in the following forms : (*a*) the bonded varieties, which consist of crystalline grains with small amounts of refractory bonds, and which are fired to high temperatures in ceramic kilns ; (*b*) bonded fire sands, which are made from carborundum fire sand and suitable bonds, "rammed in" or shaped, and burned at the place of manufacture, or are formed, shipped dry, and burned "in place" ; (*c*) refractory cements and furnace washes, which are made from crystalline grain and a series of bonds, different vitri-

fication ranges and softening points being provided for.

Chief among the modern applications of this material may be mentioned: oil-fired furnaces, high and low temperature carbonising and other retorts, porcelain enamelling muffles, glass lehrs, fireboxes, crucibles, zinc retorts, boiler settings, annealing furnaces, gas generators, muffle kilns, and radiating furnace-sand linings for non-ferrous melting furnaces. In the early days, the extreme refractoriness and great strength were thought to be the most important properties of silicon carbide refractories, but it is now recognised that their high thermal conductivity and their excellent radiating capacity render them eminently suitable for use as indirect heating units, such as retorts and muffles, considerable fuel economy being effected by their application to these purposes. It is becoming increasingly evident that these refractories are suited not so much to the replacement of natural fireclay and silica in the linings of furnaces, as to certain other uses, in which their conductive and emissive properties can be fully utilised. It is rather in this field that future development is likely to take place.

REFRACTORIES FOR ZINC SMELTING.—G. C. Stone (*J. Amer. Cer. Soc.*, **5**, 597, 1922). The refractories required in zinc smelting may be divided into five classes, depending upon the uses to which they are put: (1) roasting furnaces; (2) oxide furnaces; (3) spelter furnace linings; (4) retorts; (5) condensers. *Roasting furnaces.* The roasting of zinc ores is carried out, for the most part, in Hegeler furnaces in America. These furnaces are very large, measuring 80 ft. in length, 17 ft. wide, and 30 ft. high. As the temperatures are not excessive and there is but little corrosion or wear, the life of these furnaces is comparatively long, but the load acting on the centre wall causes it to settle badly. This settling is mainly due to the difference in temperature between the outside and centre walls, and is caused by the shrinkage of the bricks, which, in many cases, have not been burned long enough at a sufficiently high temperature. A contributory cause is the irregularity in the thickness of the bricks, necessitating heavier mortar joints than are desirable. *Oxide furnaces.* The refractories used in these furnaces have to withstand a fairly high, but not excessive temperature, with sudden drops every six or eight hours. If the ores contain much lead, corrosion from the lead fumes is very severe. The temperature does not exceed 1,000°C., but the bricks are often damaged by the sudden changes and by the somewhat severe handling in removing the charge. It has been found that dense, hard-burned bricks give the best results. *Spelter furnace linings.* These have to withstand a high temperature for long periods, with a regular daily variation between about 800° and 1,400°C. In addition to the high temperature, more or less coal ash is carried in by the gas, and slag from broken retorts gets inside the furnace. The bricks used for this purpose must withstand the high temperature and be close-grained, strong and sound. *Retorts.* The retorts are tubes with one end closed, and are from four to five feet long. The walls are about one inch thick. The retorts must be capable of withstanding a temp. of 1,600°C., and must be dense so as to be impervious to gases and zinc vapour. *Condensers.* These are usually clay cones, 16 to 20 inches long, with a diameter from 6 to 2 inches and walls about $\frac{5}{8}$ inch thick. They are not subjected to temperatures over 600°C., but they have to withstand somewhat rough handling. They should be impervious to zinc and zinc vapour.

COMPOUNDING AND PREPARATION OF BODIES, ETC.

PORCELAIN DOLLS HEADS.—(*Ker. Rund.*, **31**, 57, 1923). Dolls heads having a suitable waxy appearance can be made with a mixture containing 40 parts by weight of clay substance (Dölau china-clay), 30 parts quartz (any pure sand), and 30 parts felspar (from Wunsiedel). The fluxes—porcelain sand, pegmatite, felspar, lime, etc.—must be ground very fine, and after adding the china-clay, the whole must be ground together in the mill for a further period. Glaze troubles are often due to inadequate grinding

of the raw materials, which should remain approximately three days, or even longer, in the mill. The body must be rich in china-clay. The following is another suitable cone-12 mixture :—30 parts by weight of a white-burning porcelain sand, 20 parts felspar, 50 parts china-clay, and 1 part dolomite, or calcite.

TRIALS WITH LOW-FIRE PORCELAIN.—W. Funk (*Ber. D. K. Ges.*, **3**, 270, 1922). Following up the work of Pukall, Dorfner, and Hertwig-Möhrenbach, Funk commenced with the following bodies :

Body	No. I.	No. II.	No. VII.
Zettlitz china clay, washed	434	405	—
Sornzig do.	—	—	520
Scandinavian quartz, calcined and ground	295	251	—
Scandinavian felspar	256	292	420
Calcite, ground	15	52	60

The chemical composition of the body and glaze ingredients was as follows :

	H_2O	CO_2	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O
Zettlitz china clay	13·02	—	46·03	38·73	0·84	0·32	0·22	0·84	—
Scand. quartz ..	—	—	99·84	0·04	0·12	—	—	—	—
,, felspar ..	—	—	64·62	19·21	0·31	0·37	—	12·01	3·48
Sornzig ch. clay	11·35	—	53·20	34·71	0·29FeO	0·25	0·20	—	—
Calcite	—	42·8	1·77	0·30	0·41	54·43	0·30	—	—
Chalk	—	42·40	0·98	0·24	0·16	55·66	0·56	—	—
Magnesite ..	1·65	48·78	2·81	0·55	0·10	6·80	39·31	—	—

In bodies II and VII, the author intentionally chose the lowest limits for Al_2O_3 and SiO_2, his object being to lower the firing temperature as far as possible and thus effect economy in fuel. For these bodies, fired to cone 8–9, glazes comparatively low in alumina and silica were found most suitable ; their composition was as follows :

No. V.

36·01 felspar
8·36 Zettlitz ch. clay
19·29 chalk
5·47 magnesite
30·87 quartz.

or : 0·009 FeO, 0·614 CaO, 0·173 MgO, 0·142 K_2O, 0·062 Na_2O } 0·306 Al_2O_3 : 2·945 SiO_2

No. VIII.

33·18 felspar
12·69 Zett. china clay
16·92 chalk
4·69 magnesite
32·52 quartz

or : 0·012 FeO, 0·607 CaO, 0·164 MgO, 0·146 K_2O, 0·071 Na_2O } 0·382 Al_2O_3 : 3·413 SiO_2

Sample cups made from bodies II and VII were uniformly translucent, with a white body and smooth, polished glaze, quite free from cracks. On the other hand, both glazes appeared somewhat matt on body I. Glaze V. required a somewhat higher maturing temperature than glaze VIII. As is usually the case with bodies containing lime and fired to vitrification point, these porcelains proved to be somewhat unsatisfactory with regard to stability; the ware in the bottom, *i.e.*, the hottest, part of the kiln came out warped, whilst that in the upper part was only just fired to maturity. To test the physical properties of the fired bodies, boiling water was poured into the cups, all of which withstood this treatment without cracking. Unlike the hard, laboratory porcelain, however, this ware will not withstand the naked Bunsen flame. The fired bodies I. and VII. were submitted by Dr. R. Rieke to the ordinary strength tests, and from the tabulated results it is concluded that these too soft porcelains are approximately equal to hard porcelain of medium quality. The linear expansion of the two bodies amounts to 8 per cent. The author suggests that this type of porcelain could probably best be fired, on a commercial scale, in tunnel ovens.

THE EFFECT OF A FEW TYPICAL FIRECLAYS ON THE BEHAVIOUR OF GROG MIXTURES AT HIGH TEMPERATURES.—W. Steger (*Ber. D. K. Ges.*, **3**, 250, 1922). Our present knowledge of the nature of clays is still very limited. As an illustration of this, it is only necessary to mention the problem of substituting one clay for another in a given body, a problem which, in many cases, can only be solved after a lengthy series of trials. Chemical analysis, though important, is not sufficient; certain physical properties, which vary according to the use to which the finished product is to be put, are at least of equal significance.

The experiments described were carried out with the primary object of investigating the possibility of substituting native (German) for foreign materials in grog bodies. Starting with a given grog mixture, the effect of six different binding clays on the following physical properties was studied: Shrinkage, porosity, sagging of freely-supported rods, expansion and softening under load at high temperatures, cold crushing strength, and resistance to sudden changes of temperature. The grog consisted of ground saggars, made of Halle clay, and graded as follows: 20 parts of 10–3 mm. grain-size; 35 parts 3–1 mm., and 45 parts smaller than 1 mm. The powder was removed by a 900-mesh sieve. Rational analyses of the six clays gave residues, after digesting with H_2SO_4 (Berdel method), varying from 53·9 to 2·6 per cent.; the melting points varied between cone 29 and cone 35. For the purposes of the tests, rods, plates and cylindrical blocks were made, and fired to cone 04a and cone 16 in an industrial kiln.

Results:—Owing to the low content of binding clay, no typical variations in linear shrinkage or volume porosity were observed. The Halle clay exhibited a slight expansion due to a high quartz content. For the sagging tests, rods measuring $25 \times 2 \times 1$ cm. were supported on prisms 20 cm. apart and fired to cone 16. The individual clays showed characteristic variations, depending upon their content of free quartz and fluxes. No relationship was observed between the melting point in cones and the amount of sag. Cylindrical blocks 5 cm. in diameter and 5 cm. high were used for testing the expansion and softening under load at high temperatures. The samples were fired under identical conditions to cone 16. The temperatures at which softening commenced varied, with one exception, by only 50° (1,300–1,350°). On the other hand, sharper distinctions were noted between each of the clays when the samples were subjected to three firings to cone 16. The maximum variations in softening temperatures then increased to 110°. These temperatures were lower (in one case by 70°) except in the case of the Halle clay, which contained much sand. The curves no longer exhibited the slow, progressive yielding after softening temperature had been reached, but fell away rapidly, indicating increased vitrification in the bodies owing to repeated firing. The cold crushing strength was found to be characteristic of each clay. It varied from about 2,844 to 597 lb. per sq. in. The resistance to

sudden change of temperature was tested by (1) heating samples to 1,000°, and (*a*) cooling at room temperature on an iron plate ; (*b*) quenching in cold water, and (2) by similar tests after firing to 1,300°. The cold crushing strength was unaffected in every case by these tests. The results, it is concluded, indicate that, by a suitable choice of testing methods, the characteristic behaviour of different clays can be determined satisfactorily. If this claim is vindicated in practice, the methods suggested will represent an important step toward the solution of the problem of substituting one clay for another.

AN IMPROVEMENT IN THE MANUFACTURE OF VESSELS USED IN RETORTING ZINC ORES.—J. P. Varian (*Eng. Min. J.*, **113**, 363, 1922).

SOME FLOORING BODIES CONTAINING CHINA CLAY AND CHINA STONE.—(*China Rev.*, **5**, 87, 1922). A list of 24 body mixtures, for various colours, is given.

SOME PROPERTIES OF ZINC OXIDE BODIES.—E. E. Libman (*J. Amer. Cer. Soc.*, **5**, 488, 1922). The melting point of ZnO is above 1,800°C., and may be above its normal sublimation point. The material used in experiments was "chemically pure," containing only slight traces of Fe and Pb. (0·01%). With pure ZnO a very hard and dense body can be prepared. At high temp. it exhibits the unusual property of volume shrinkage accompanied by an increasing porosity. In the discussion, E. W. Washburn suggests that with Al_2O_3 (fire clay), SiO_2 and ZnO a highly refractory zinc retort could be manufactured. A retort body might also be obtained which would be practically unattacked by the charge.

DATA ON THE VISCOSITY OF INDIANA CLAY SLIP WITH ELECTROLYTES IN REGARD TO THE CASTING OF TERRA COTTA.—H. E. Davis (*J. Amer. Cer. Soc.*, **5**, 702, 1922). The effect of several electrolytes on an Indiana clay, as used by the terra cotta manufacturers of the Chicago district, was studied with a view to developing, if possible, a process of economically casting such work as small free-standing ornaments, balusters, etc. The electrolytes used were : sodium carbonate, sodium silicate, these two combined in equal proportions, gallic acid and tannic acid. The relative viscosities were determined by the aid of a home-made viscosimeter and by measuring the thickness of wall cast in a given time. The results obtained are tabulated and plotted. The most satisfactory results were obtained with sodium carbonate used alone. Tannic acid was found to have certain distinct advantages, such as making a slip of excellent working qualities, losing its water very readily, etc., but so much is required as to render its commercial application impracticable.

TALC AS A FLUX FOR HIGH-TENSION INSULATOR PORCELAINS.—R. Twells (*J. Amer. Cer. Soc.*, **5**, 675, 1922). MgO may best be introduced as a flux in porcelain bodies in the form of talc, which is cheap, and does not necessitate a large percentage of calcine. In the experiments described, a typical high-tension insulator body of the general formula : 0·21 K_2O, 1·0 Al_2O_3, 4·45 SiO_2 was used as a standard. The K_2O was partially replaced by MgO, (talc being used as its source) and the RO was varied between 0·14 and 0·30 equivalents. The bodies were fired to cones 9 to 11, and were tested in most cases for absorption and transverse strength only. The results at cone 10½ indicate that (1) a small addition of talc greatly decreases the percentage of felspar necessary for vitrification ; (2) further small increments have much less effect than the first ; (3) about 0·16 equivalents of RO are needed for vitrification at this temp when small percentages of talc are used. This corresponds to about 15 to 22·5% felspar and about 2·5 to 0·75% of talc ; (4) in the properly vitrified bodies the addition of the MgO at the expense of K_2O tends to increase the transverse strength. Vitrified bodies of this general type show little improvement over regular triaxial porcelains. It is suggested that, as the next logical step, the effect of the

replacement of felspar entirely, or almost entirely, by talc, and the application of higher temperatures to obtain vitrification, should be investigated.

PATENTS.

SILICA BRICKS.—Pease & Partners, Ltd. & J. Wilson (*Pat. J.*, 1,788, 1923). No. 193,999, Dec. 8, 1921. The mixture consists of 96% silica, 2½% china clay and 1½% lime. The china clay and lime are suspended in the water with which the powdered silica is rendered plastic.

REFRACTORY COMPOSITION.—Schaefer et Cie. and H. Schaefer (*Pat. J.*, 1,794, 1923). No. 196,021, Dec. 13, 1921. Waste siliceous bricks, which have been used in furnaces, or quartz which has undergone crystalline transformation, are ground and mixed with an organic binder, soluble in water, such as dextrine, amylaceous materials, albuminoids, glucosides, etc. Suitable proportions are 100 parts powder to 5 parts binder. The mixture is moulded, dried, and burned in situ.

POTTERY BODIES.—M. Bacchiolelli and A. M. Devals (*Pat. J.*, 1,795, 1923). No. 196,342, 14 Jan., 1922. Igneous rocks such as lava, basalt, dolerite, etc., are crushed to powder and agglomerated by heat treatment (with or without shortening materials) at a temp. below their melting points. The body can be shaped, moulded or cast in the usual way.

SHAPING, MOULDING, DRYING, ETC.

PATENTS.

ELECTRIC INSULATORS.—Soc. Ceramica Richard Ginori (*Pat. J.*, 1,796, 1923). No. 196,604, Apr. 16, 1923. A suspension insulator is formed with two or more passages angularly displaced relatively to one another and with one of the passages lying completely outside the bell of the insulator.

MOULDING FANCY TILES.—Soc. Anon. La Céramique Nationale (*Pat. J.*, 1,796, 1923). No. 196,906, Apr. 10, 1923. Fancy tiles with coloured inlays are made by supplying the colours to the mould through an appropriate counter-pattern fitting the mould frame, and co-operating with a stencil within the mould.

ROTARY MOULD-TABLE MACHINES FOR PATTERN TILES.—Soc. Anon. la Céramique Nationale (*Pat. J.*, 1,796, 1923). No. 196,907, Apr. 10, 1923. A machine is described for moulding patterned tiles as indicated in Spec. 196,906 (above). A series of feeding devices for colour and body material, together with pressing and delivery mechanism, is provided.

KILNS, OVENS, MUFFLES; FIRING TECHNIQUE, ETC.

HEATING WITH HOT AIR.—(*Sprech.*, **56**, 133, 1923). Owing to the scarcity of coal in Germany, the raising of steam for power purposes is being abandoned to an increasing extent in favour of electricity. The main disadvantage of steam heating lies in the fact that, though it provides the necessary warmth, it does not produce the requisite ventilation. The atmosphere in the rooms tends to become very moist and warm, so that, when a window or door is opened, moisture is immediately deposited. Better drying, heating and ventilating conditions are obtained if waste heat from the kilns is used. This is usually effected by dampering off the chimney flue of a kiln when firing is completed. By means of a fan, air is then drawn through the grate and the chambers. This hot air is conducted through a special flue, lined with refractory material, to a mixing and dust-collecting chamber, whence it is forced under pressure from the fan to the places where it is required. The hot air in the metal pipes has a temperature of not more than 120°C. under these conditions, so that there is no danger of fire owing to pipes becoming red hot. The mixing chamber also serves as a heat reservoir, and thus the hot air can be maintained for a lengthy period at a fairly constant

temperature. This temperature is sufficiently low to permit the use of galvanised piping, thus eliminating the danger of impurities, such as rust, reaching the ware.

THE A. E. G. OPTICAL PYROMETER.—(*Sprech.*, **56**, 211, 1923). The A. E. G. optical pyrometer is a simplified form of the Holborn-Kurlbaum type. It registers temperatures between 650 and 1,500° accurately to within ± 5°C. It is based on the principle of the disappearing filament, and is extremely simple in construction. It consists mainly of a central optical tube, in the fore part of which a carbon filament lamp is fixed. This tube is encased within a second, upon which is a double-wound, non-inductive resistance coil. A third, protective tube, which carries the temperature scale, covers the resistance tube. In addition, this outer tube is fitted with a slide, which is in contact with the resistance. The instrument is provided with a grip which is held in the left hand, the right being free to manipulate the slide.

The pyrometer is graduated in accordance with the voltage of the supply cable ; any variations in voltage must therefore be allowed for in making exact measurements. The temperature correction for a variation of one volt is given on the slide. For instance, if, in using a 220-volt pyrometer, the correction for which is ±2° per volt, the voltmeter registers 222 volts, the true temperature will be 4° higher than that indicated on the scale.

The instruments are made to operate both an A.C. and D.C. circuits up to 220 volts ; for an A.C. voltage of over 220 a transformer is necessary. For voltages up to 190 the pyrometer may be coupled up directly with the supply cable.

AUTOMATIC STOKING OF CONTINUOUS KILNS.—A. Minne (*Cer.* **26**, 25, 1923). A description of the "Columbus" automatic stoker is given. This apparatus feeds each fire regularly with fuel in small quantities which can be exactly proportioned to the volume of air drawn off by the chimney or fan. The amount of fuel charged can thus be regulated according to the condition of the fire.

NOTES ON INTERMITTENT AND CONTINUOUS CERAMIC KILNS.—R. M. A. (*Cer.* **26**, 50, 1923). Mainly a theoretical consideration of the subject.

THE VALUE OF GAS ANALYSIS ON GLASS WORKS.—(*Sprech.*, **56**, 210, 1923). The method of determining the composition of "dry" generator gas is outlined.

FUEL CONSUMPTION IN ANNULAR KILNS.—K. Dümmler (*Deut. Töp. Zieg. Ztg.*, **54**, 143, 1923). The chief advantage of annular kilns over other types lies in the fact that the heat stored up in the fired bricks can be utilized to preheat fresh ware. By a theoretical calculation it is shown that, in order to transfer effectively the heat, five times more air passes through the kilns than is actually required to effect complete combustion of the coal.

WATER SMOKING WITH INDUCED DRAUGHT.—W. W. Ittner (*J. Amer. Cer. Soc.*, **5**, 721, 1922). Some experiences are related in which, by means of induced draught, the periods of water smoking and of burning dry-pressed bricks were shortened, with a saving of fuel. The writer concludes that a light, portable exhauster, arranged for easy attachment to the kiln, or to the tunnel between the kiln and the stack, would prove economical in many plants.

THE PROPAGATION OF FLAME IN COMPLEX GASEOUS MIXTURES. PART V. THE INTERPRETATION OF THE LAW OF SPEEDS.—W. Payman (*J. Chem. Soc.*, 123/4, 412, 1923).

ON THE MEANING OF THE THERMAL EFFICIENCY OF FURNACES, AND SOME ERRORS OF A. BIGOT.—M. Korach (*Faenza*, **10**, 151, 1922). A theoretical discussion.

GAS ANALYSES.—M. Lefèbure (*Verre*, **32**, 55, 1923). The Orsat apparatus is described and the method of using it is outlined.

PRELIMINARY REPORT OF THE COMMITTEE ON FUEL CONSERVATION ON THE RAILROAD TUNNEL KILN.—S. M. Kier and A. F. Greaves-Walker (*J. Amer. Cer. Soc.*, **5**, 602, 1922). The report is divided into three parts. Part I. gives the historical development of the tunnel kiln and a general description of its construction, etc. In Part II. a number of American tunnel kilns are described. Part III. deals with firebricks. It is concluded that, given a kiln of suitable length, proper proportioning and sizing of the raw materials, and the correct firing temp., there is no reason why all refractory fireclay bricks should not be fired successfully in tunnel ovens.

AN OIL-FIRED FURNACE FOR THE PLANT LABORATORY.—D. A. Moulton (*J. Amer. Cer. Soc.*, **5**, 713, 1922). An illustrated description is given of an iron-encased furnace, with 1½-inch asbestos insulation. The chamber is 21 in. square by 20 in. high, and will hold 14 bricks on end. The furnace requires from 16 to 20 gallons of fuel-oil per heat of high temperature for a period of 5 hours. Pre-heated air is supplied by a No. 4 blower running at 3,000 r.p.m. delivered through a 3-inch pipe.

TUNNEL OVENS; PROPELLING TRUCKS.—K. Dümmler (*Deut. Töp. Zieg. Ztg.*, **54**, 95, 1923). It is suggested that less power would be required for propelling the trucks through tunnel kilns, if the latter are built in an inclined position from the entrance downward. To maintain the trucks in a horizontal position, both inside and outside the kiln, two sets of rails are needed. The trucks are so constructed that the front wheels run on the outer pair of rails and the rear wheels on the inner pair. The front wheels have grooved tyres—the rails being shaped accordingly—so that, outside the kiln, they will run smoothly over a level floor, only one pair of rails being then required.

IMPROVEMENTS IN CONNECTION WITH GAS REVERSING VALVES FOR REGENERATIVE FURNACES.—F. W. Knowles (*J. Soc. Glass Tech.*, **6**, 220, 1922). To prevent the underside of the valve seating from becoming burnt and distorted, the bedplate of the valve is lowered about 3″ and separated from the side of the port, leaving a channel open to the atmosphere at both ends, thus providing air-cooling to that portion of the valve seating which is usually built up solid (one illustration).

Patents.

PYROMETERS.—B.S.A. Co. and A. R. Page (*Pat. J.*, 1,788, 1923). No. 194,094, Feb. 1, 1922. The arrangement of a thermo-electric pyrometer system, employing a series of thermo-couples and a single meter, is described.

ROTARY FURNACES.—Sheet Metal Workers, Ltd. (*Pat. J.*, 1,789, 1923). No. 194,688, Feb. 26, 1923. The furnace described comprises, *inter alia*, a construction of the furnace shell, a mounting therefor, and means for utilising the expansion of the furnace for indicating the temperature conditions and controlling the gas supply.

TUNNEL OVEN.—J. Cockerill (*Pat. J.*, 1,792, 1923). No. 195,590, Oct. 20, 1922. A tunnel oven for burning bricks, etc., is divided into a number of zones, in which different operations can be carried out independently of one another. The cooling zone is divided by a pair of dampers into two sections, through one of which the air for combustion is drawn by a fan.

COKE OVENS: PREVENTING "HOT POINTS" IN FLUES.—P. E. Verpeaux (*Pat. J.*, 1,794, 1923). No. 196,264, Mar. 23, 1923. Relates to regenerative coke ovens in which the direction of flow of the heating-gases is reversed, and comprises a method of controlling the heating so as to prevent the occurrence of "hot points" in the flues.

GLAZES, ENAMELS.

ZIRCONIUM FLUORIDE GLAZES.—F. Kraze (*Ber. D. K. Ges.*, **3**, 157, 1922). Zirconium fluoride glazes are suitable for porous bodies containing

little lime. The raw materials employed in their preparation are: sodium silicofluoride, cryolite, calcined soda, potassium felspar, quartz, barium peroxide, and "zirkonsilite." The latter is a finely-ground, and, in spite of its low price, well assorted zirconium ore, obtained from the mines of Sao Paulo, in Brazil. Its chemical analysis is as follows: 79·05% ZrO_2, 15·7% SiO_2, 0·48% TiO_2, 1·45% Fe_2O_3, 0·72% Al_2O_3, 2·75% loss on ignition. A glaze made with this material without fluorides has a satisfactory gloss, but a very pronounced yellowish-brown colour, due, probably, to iron titanate. The ZrO_2 itself is converted, in the presence of fluorine, into ZrF_4, which produces the cloudiness in the glaze, whilst ZrO_2, when fritted without fluorides, is dissolved in the fluxes, and thus produces no cloudy effect. The purified zirconium silicate known as Terrar, containing 75—80% ZrO_2, is effective only if it is added in the mill-mixing, but in this case it is merely distributed mechanically, and not chemically, in the glaze. Since fluorine, or its salts, is an important constituent of these glazes, the addition of boron compounds would be a mere waste of boric acid, or of borax, for the result would be the volatilization of considerable quantities of boron fluoride. If the "zirkonsilite" is fritted both with fluorides and with boron compounds, with the intention of rendering the frit more fusible, not only is the above-mentioned volatile boron fluoride formed, but the efficiency of the zircon fluoride in producing the necessary cloudiness is remarkably decreased, the fluorine having a greater affinity for boron than for zirconium. On the other hand, the gloss is improved by the boron.

The molecular structure of a cone-05a zirconium fluoride glaze is indicated in formulæ I.—III. During fritting, primary silicon fluoride is formed from the sodium silicofluoride and secondary SiF_4 from the sodium fluoride of the same compound.

I.	0·323 Na_2O 0·412 Na_2F_2 0·214 K_2O 0·051 BaO	0·412 SiF_4	0·234 Al_2O_3	3·029 SiO_2 0·184 ZrO_2
II.	0·323 Na_2O 0·412 Na_2O 0·214 K_2O 0·051 BaO	0·234 Al_2O_3	3·029 SiO_2 0·184 ZrO_2	0·412 SiF_4 0·412 F_2=0·206 F_4.
III.	0·735 Na_2O 0·214 K_2O 0·051 BaO	0·234 Al_2O_3	3·007 SiO_2 0·184 ZrF_4	(04·34 SiF_4).

Formula III. excluding the portion in brackets, gives the probable constitution of the finished glaze. The ZrO_2 has been converted into the cloudy ZrF_4, and has thus taken up 0·184 molecule of F_4, leaving 0·206—0·184=0·022 mol. of F_4 to be accounted for; this requires 0·022 of Si, or 0·022 of SiO_2 for 0·022 mol. of SiF_4. There remains, therefore, 3·029—0·022=3·007 mol. of SiO_2. To the 0·022 SiF_4 must be added the 0·412 mol. SiF_4 from the sodium silicofluoride, so that a total of 0·434 mol. SiF_4 is volatilized. In I. to III., 0·020 of $Al_2O_3.2SiO_2.2H_2O$ is not fritted with the glaze, but added in the mill mixing. An increase of ZrO_2 renders the glaze less fusible; further, the alkalies cannot be replaced by the equivalent of ZrO_2, without decreasing the fusibility. In III. the maximum of "zirkonsilite" content has been reached. In order to produce the same cloudy effect with less "zirconsilite," cryolite must be added, as in the following glaze:

IV.	0·728 Na_2O 0·243 K_2O 0·029 BaO	0·301 Al_2O_3 0·035 Al_2F_6	3·161 SiO_2 0·061 ZrF_4	(0·067 SiF_4)

Of these, 0·058 $Al_2O_3.2SiO_2.2H_2O$ is added in the mill. Fritting should be done in pot ovens, so that volatilization of the fluorine can be facilitated

by a thorough stirring of the mixture. Fritting and stirring must be continued until the bubbling has ceased and the surface has become smooth and quiet. The frit is then poured into water, mixed with clay, and ground. If it still contains much SiF_4, volatilization continues in the glost oven, and the glaze may easily come out with a matt surface. This is illustrated very clearly by an experience which the author had with zirconium fluoride enamels for iron, which closely resemble the glazes for pottery. In these enamels, a much better gloss was obtained when the ratio of ZrO_2 to sodium silicofluoride did not exceed 1 : 1 (as in glaze IV.), than when it reached 1 : 2, as in glaze III. In the latter instance, the gloss was readily removed by cold water. But it is important to note, that this phenomena only appeared when the vessels were fired in an inverted position, *i.e.*, with the opening downward. This is explained by the fact that the chemically free SiF_4 is volatilized in the kiln and, in endeavouring to escape, collects inside the vessel, forming a fluorine salt rich in alkalies on the bottom. This salt, however, is very soluble in water, and mere contact with tap water suffices to remove the gloss. But this gloss is completely restored if the vessels are again passed through the kiln, mouths upward, and this time it is a permanent gloss, which is resistant even to weak acids. It follows, therefore, that, when zirconium fluoride glazes are employed, suitable apertures must be provided in saggars, or proper ventilation in muffles, in order to allow the fluorine gases to escape. It is better to run off the frit dry and allow it to cool slowly, rather than to quench it in water. The separation of zirconium fluoride takes place most satisfactorily during a slow cooling, so that, in this way, the cloudy effect is more readily produced in the glaze, and a lower glost temperature is required.

THE ADJUSTMENT OF BODY AND GLAZE.—A. Granger (*Cer.*, **25**, 329, 1922). Le Châtelier's statement that the problem of adjusting body and glaze is simply a physical one, is disputed by the author, who points out that a variation between the two coefficients of only 0·00000009 does not ensure safety. The theory is at fault for the following three reasons: (1) It takes no account of possible chemical reactions between body and glaze. (2) It does not allow for the elasticity of the glaze. If, for the sake of simplicity, the coefficients of expansion for a number of bodies and glazes are multiplied by 108, figures are obtained from which the following remarkable conclusion is drawn: With a variation of 9, immunity from crackling is by no means assured, whilst with a difference of 200 results are satisfactory in practice. (3) No account is taken of the vitreous nature of the glaze. Analogous conditions are met with in glass making. It is desired to seal a metallic wire into a glass tube, the operation will be found to be comparatively easy with platinum or copper, but more difficult with iron. Yet the coeff. of expansion of iron occupies an intermediate position between those of platimum and copper. The explanation is to be found in the fact that iron is harder than the other two metals. As the glass solidifies, a certain pressure is exerted on the metals; the softer ones tend to "give," while the harder iron resists the pressure, causing the glass to crack. Glass does not pass abruptly from a liquid to a solid state, but remains for a certain period in a viscous condition. This viscous interval is not the same for all glasses. In the process known as "casing" (covering plain with coloured glass, analogous to glazing in ceramics), a glass with a short viscosity interval will be much more difficult to work with than one with a longer interval. If one glass loses its viscosity before the other, the stresses set up between the two will be taken up by the still viscous glass until the latter also solidifies. A similar phenomenon occurs between pottery bodies and glazes. The important point therefore, is to obtain a glaze with a long viscosity interval. A certain flux is used at Sèvres, containing 30·64% quartz sand, 45·2 minium, 19·34 china clay and 5·65 lime, which, although fusible at cone 05, will sustain a much higher temperature. On fusing, lead silicate is first formed, then the lime begins to combine with the silica, but the kaolin decomposes but slowly. Once fused and ground, this mixture can be used to glaze

various types of pottery simply because of its great viscosity. It commences to fuse much below cone 05, but does not mature properly until this temperature is reached.

ON THE EFFECT OF ZINC OXIDE ON UNFRITTED, LEADLESS GLAZES FOR SANITARY EARTHENWARE.—E. P. Bauer (*Ber. D. K. Ges.*, **3**, 286, 1922) Reference is made to previous research work, details of which appeared in the *Trans. Amer. Cer. Soc.*, of 1903 (R. C. Purdy) and 1908-9 (R. T. Stull), and to the work on the substitution of ZnO for BaO or MgO by Stull and by R. H. Minton (*Journ. Amer. Cer. Soc.*, 1920). This has been extended by the author, who carried out tests with the object of determining the effect on the two glazes used by Stull of substituting ZnO in varying amounts for the metallic oxides K_2O, CaO, BaO, and MnO. The glazes were applied to an ordinary cone-8 earthenware body. Stull's glazes were:

I. $\left.\begin{matrix}0{\cdot}3\ K_2O\\0{\cdot}4\ CaO\\0{\cdot}3\ BaO\end{matrix}\right\}\ 0{\cdot}4\ Al_2O_3 : 4\ SiO_2$ II. $\left.\begin{matrix}0{\cdot}5\ MgO\\0{\cdot}3\ K_2O\\0{\cdot}2\ CaO\end{matrix}\right\}\ 0{\cdot}5\ Al_2O_3 : 4\ SiO_2$

Bauer proceeded to substitute 0·1 equivalent of ZnO for each 0·1 equiv. of the metallic oxides; and, in order to test the effect of a higher ZnO-content, he carried this process still further, by submitting a second oxide to this substition treatment in glazes in which one RO had already been replaced by ZnO. The two glazes of this series were, therefore:

III. $\left.\begin{matrix}0{\cdot}3\ ZnO\\0{\cdot}4\ CaO\\0{\cdot}3\ BaO\end{matrix}\right\}\ 0{\cdot}4\ Al_2O_3 : 4\ SiO_2$ IV. $\left\{\begin{matrix}0{\cdot}5\ ZnO\\0{\cdot}3\ K_2O\\0{\cdot}2\ CaO\end{matrix}\right\}\ 0{\cdot}5\ Al_2O_3 : 4\ SiO_2$

Trials were made and fired to cones 5a—6a, 7—8, 9—10, and 10—11, an oxidising atmosphere being maintained throughout in the kiln, which reached cone 10—2 in 12 hours.

The following is a summary of the results:—

GLOSS. Glaze Series I. *and* II.—The higher the firing temperature, up to cone 9—10, the better the gloss. With an equimolecular increase in the ZnO-content, loss of BaO affected the glaze less than loss of K_2O, or even CaO. Small quantities of K_2O can be replaced by ZnO without materially altering the gloss. Scarcely any change was noted in the gloss in the variation from 0·5 MgO+0·0 ZnO to 0·0 MgO+0·5 K_2O. The glaze with 0·4 ZnO and 0·1 MgO proved to be the best and most uniform at all temperatures.

Glaze Series III. *and* IV.—The unfavourable effect of loss of K_2O was also evident with glaze IV., but loss of CaO was not detrimental. With glaze III. it was obvious that a high percentage of ZnO in place of BaO and CaO improved the gloss. A very marked improvement was obtained by firing the CaO-free glaze to cone 10 (0·4 ZnO-content).

OPACITY. Some of the glazes were quite indistinguishable from a commercial tin glaze.

Glaze Series I. Scarcely any opacifying effect was observed. The Al_2O_3-content (0·4) was obviously too low. Some degree of success was attained in this series with alkali-free glaze. The ZnO was not, in this case, dissolved by the fluxes BaO and CaO, but was suspended in a finely-divided condition in the glaze. This condition, though favourably to opacity, had an adverse effect on the gloss. It would therefore not be advisable to omit the felspar.

Glaze Series II. Exchange of MgO for ZnO did not alter the covering capacity of the glaze. By increasing the ZnO-content, the glaze colour was changed from a yellowish to a pure white colour.

Glaze Series III. and IV. In these series it was to be assumed that, with an increased ZnO-content, the ZnO would not be completely dissolved. Opacity was, therefore, to be expected in all the glazes of this series. However, these expectations were not entirely fulfilled. The desired effect was produced only in the series in which substitution for CaO was carried out. A low percentage, or even complete absence of CaO, would therefore appear desirable, in order to obtain a pure white glaze. However, no confirmation

of this was secured from Series IV., in which the absence of alkalis probably played an important part. The following glaze:

$$\left.\begin{matrix} 0{\cdot}7\ ZnO \\ 0{\cdot}3\ K_2O \end{matrix}\right\} 0{\cdot}5\ Al_2O_3 : 4\ SiO_2$$

proved of great interest, since it produced a really pure white, exactly similar to a typical tin glaze. Fired to cone 8, this glaze has an excellent gloss and shows no evidence of crazing. It therefore removes all doubt as to the practical possibilities of leadless, ZnO-containing glazes.

FUSIBILITY. It was found, without exception, that the melting temperature was increased by substituting ZnO for the metallic oxides. (In this respect Stull's data appear to be incomplete).

EXPANSION COEFFICIENT. Most of the glazes were quite free from cracks, so that the coefficients of expansion were satisfactory. They corresponded closely with the theoretical values obtained from the Winkelmann-Schott formula.

THE EFFECT OF HEAT-TREATMENT AND BODY-COMPOSITION ON CRAZING OF SEMI-PORCELAIN.—I. E. Sproat (*J. Amer. Cer. Soc.*, **6**, 510, 1923). The results of research work and observation in some of the leading semi-porcelain factories of America, covering a period of three years, are summarised by the author. The entire work was conducted under factory conditions and was confined to practical general bodies and glazes. *Thickness of Glaze.* In the ordinary dipping process it is practically impossible to produce ware with a uniform thickness of glaze, even if the body has the same absorption, which, under works conditions, is rarely the case. The glaze on several pieces may appear to the eye to be of uniform thickness and yet have sufficient variation in thickness to show differences in crazing behaviour. In order to produce ware with as little tendency to craze as possible, the dipping should be carried out in such a way that the glaze is of uniform thickness over the whole piece, and as thin as possible without showing dry edges. Since these conditions are impossible of achievement with modern works methods, the author suggests that some form of mechanical dipper is required. The comparatively simple, yet highly important process of dipping should lend itself admirably to mechanical treatment.—*Porosity* is also of great importance. An improved type of kiln, which would produce ware of comparatively uniform absorption (2% maximum variation) would be a great aid to the industry. The writer suggests that, if the hot zone of a Dressler kiln were lengthened by 20 or 30 feet, giving an increase in the total length of from 50 to 70 feet, and the width of the tunnel decreased considerably, the result would be a kiln closely approaching the ideal.—*Effect of glaze composition.* On making sufficient change in the composition of the glaze to produce a marked decrease in crazing, it was found that one or more of the other essential properties had been adversely affected; *e.g.* the high silica glazes showed the least tendency to craze, but they were too viscous and did not flow readily at cone 1.—*Effect of body composition.* Investigations showed that, by the use of from 10 to 15% of a new clay from Missouri, sold under the trade name of "Hercules," a good practical body could be made free from crazing. "Hercules" clay is described as a sort of cross between a ball-clay and a china-clay. It has a modulus of rupture of 325 lb. per sq. in., a drying shrinkage of 6% and a total shrinkage of 14% at cone 8. It contains 61% of silica, a fact which explains its property of counteracting crazing. No other change in body composition was found possible without seriously interfering with other essential properties.—*Effect of variation in absorption.* Contrary to the opinion generally held by potters, the tendency to craze was not increased by every increase in absorption. The greatest resistance to crazing was obtained with bodies having an absorption of from 7 to 12%. This gives a permissible variation of about 5%, which is ample for good firing conditions in periodic kilns.—*Effect of the time-temperature of the glost burn.*—It became evident from the results obtained, that by increasing the time of firing a glost kiln by 6 hours or more, within the practical limits of 18-30 hours, a very decided decrease in crazing can be attained.

As a means of decreasing crazing, the time factor is undoubtedly of great importance. If crazing occurs in practice, the first and best thing to do is to increase the time of firing the glost kiln if it is less than 30 hours. This procedure is by far the most logical thing to do, regardless of the direct cause of crazing. But it is important to remember that it is the maturing time of the glaze which must be increased in order to diminish crazing.

THE USE OF OX GALL TO PREVENT CRAWLING OF GLAZES.—H. Spurrier (*J. Amer. Cer. Soc.*, **5**, 937, 1922). A preparation of ox gall is sometimes used by artists to cause water colours to "take" on paper which has become greasy. This fact was made use of in one instance, in which it was desired to glaze over an underglaze decoration in which the medium was oily, so that a single fire might suffice instead of the usual two-fire method. A small quantity of the liquid, as used by artists, was added to the glaze, which then covered well, and the pieces, after firing as usual, came out very well. An effort was then made to discover other, and less expensive materials than the ox gall preparation, but only one, viz., sulphonated castor oil, or Turkey red oil, appeared to serve the purpose, and that not very satisfactorily. Subsequently, it was found that excellent results could be obtained with gall in the paste form, known as inspiscated ox gall, which is much cheaper than the prepared variety.

Very small quantities of gall suffice to cure aggravated cases of glaze crawling. In one instance, a glaze batch of over 200 lbs. of solids of blue glaze was completely cured of severe crawling by the addition of 3 oz. of gall dissolved in part of the added water. Previously, no perfect specimens could be produced with this glaze, but after the above treatment with ox gall not a trace of crawling could be found. The gall appears to have the effect of producing a much more intimate bond between the glaze and the unfired body. Its action is due, in all probability, to a decreased surface tension.

THE RELATION OF FINENESS OF GRINDING TO OPACITY IN WHITE ENAMELS.—B. T. Sweely and E. S. Prince (*J. Amer. Cer. Soc.*, **5**, 855, 1922). A short paper, in which it is shown that the most important factor influencing the production of uniform opacity in enamels is the mill treatment to which the mixture is subjected. By carefully testing the fineness of grinding before putting the enamel to use, much of the variation in the opacity can be eliminated. A table showing screen analyses of white enamels is given.

MANUFACTURE OF SINGLE COAT GRAY ENAMELLED WARE.—H. C. Arnold (*J. Amer. Cer. Soc.*, **5**, 858, 1922). The preparation of the black shape is described. It has to be covered completely in one coat, since the lack of a second, or covering coat makes it impossible to hide a blemish or scratch. In the single coat gray enamel, the clay functions as the opacifier, as well as the suspending medium. A plastic kaolin gives best results. The variations between single-coat and multi-coat practice are pointed out. The single coat must have the gloss and lustre of a finished coat, and must show two colours, produced from the same enamel in a single dipping.

THE RELATIVE MERIT OF HEAT-RESISTING ALLOYS FOR ENAMEL BURNING RACKS.—E. P. Poste (*J. Amer. Cer. Soc.*, **5**, 811, 1922). Several metals were studied with regard to oxidation and warpage at a temp. of 1700—1800°F. These are grouped in the order of increasing warpage and oxidation.

THE USE OF PULSICHROME FROM A MANUFACTURER'S STANDPOINT.—E. Clark (*J. Amer. Cer. Soc.*, **5**, 826, 1922). The advantages of the pulsichrometer for applying glazes are set forth. In the pressing room the pulsichrometer gives the ware a very uniform appearance. In the glazing department better and more rapid application is possible in one operation. The greatest advantage is in the kiln department, where re-burns are eliminated, while in the fitting department the ware can be handled with greater speed.

ANTIMONY GLAZES.—W. Rohn (*Ker. Rund.*, **31**, 31, 1923). In order to obtain a brilliant yellow colour, the following three factors must be carefully observed: (1) the initial glaze must be of correct composition; (2) a purely oxidising fire must be maintained; (3) the glaze must have a certain translucency. With regard to the effect of the various elements upon the development of the colour, the alkalies occupy the most prominent position. In a glaze in which the RO consists of 0·8 to 0·9 mol. PbO and 0·1 to 0·2 mol. KNaO the alkalies always produce better colours than when the RO is composed exclusively of PbO. Exceptionally good results were obtained with an RO composed of 0·1 to 0·2 Na_2O and 0·8–0·9 PbO, and it is assumed that the sodium is particularly effective in inducing the formation of Naples yellow. On the other hand the earth alkalies, with the exception of magnesium, destroy the colour almost completely. Barium and calcium affect the colour to an approximately equal degree, but with strontium an almost colourless, semi-opaque effect is obtained with a glaze in which the RO is composed of 0·8 PbO and 0·2 SrO.

Zinc, alumina and silica have no effect upon the formation of antimony-lead glazes. Similarly, boric acid has no direct effect, though it produces a better gloss, making the colour appear more brilliant. The effect of the various elements can be seen from the following table:—

No.	Glaze	Effect
1.	0·8 PbO, 0·2 K_2O } 0·15 Al_2O_3 : $2SiO_2$+3% Sb_2O_3	Good yellow. (Dirty ochre yellow with 6% Sb_2O_3)
1*a*.	0·8 PbO, 0·2 K_2O } 0·15 Al_2O_3 { $2SiO_2$, 0·4 B_2O_3+3% Sb_2O_3	Good yellow.
2.	0·8 PbO, 0·2 Na_2O } 0·15 Al_2O_3 : $2SiO_2$+3% Sb_2O_3	Very good yellow. (Less clear with 6% Sb_2O_3 or SnO_2).
2*a*.	0·8 PbO, 0·2 Na_2O } 0·15 Al_2O_3 { 2 SiO_2, 0·4 B_2O_3+3% Sb_2O_3	Brilliant egg-yellow; dirty with 6% Sb_2O_3
3.	0·8 PbO, 0·2 MgO } 0·15 Al_2O_3 : 2 SiO_2+2% Sb_2O_3	Yellow; dirty with 4% and thin with 8% Sb_2O_3
4.	0·8 PbO, 0·2 BaO } 0·15 Al_2O_3 : 2 SiO_2+3% Sb_2O_3	Thin yellow.
5.	0·8 PbO, 0·2 CaO } 0·15 Al_2O_3 : 2 SiO_2+3% Sb_2O_3	Thin yellow.
6.	0·8 PbO, 0·2 SrO } 0·15 Al_2O_3 : 2 SiO_2+3% Sb_2O_3	Almost white; same effect with 5% Sb_2O_3.
7.	0·8 PbO, 0·2 ZnO } 0·15 Al_2O_3 : 2 SiO_2+3%Sb_2O_3	Yellow; dirty with 5% Sb_2O_3.

Glaze 2*a* gives a very brilliant egg-yellow colour, not to be obtained with an RO composed only of PbO. The addition of iron oxide in small quantities has the effect of producing a beautiful orange tint. In order to obtain a really brilliant egg-yellow colour, the glaze must be somewhat translucent, for if the glaze is opaque the colour tends to appear dull. The addition of from 1 to 3 per cent. of antimony oxide gives the best results; if present in excess of 4 per cent. this compound has a "masking" effect on the colour. The addition of 6 per cent. tin oxide to a good yellow glaze converts the

colour to a ochre yellow. In glazes free from earth alkalies, the yellow coloration commences with about 0·35 mol. PbO present; no marked change of colour is observed with more than 0·8 mol. present. By suitably reducing the alumina and silica content, the glaze can be adapted to the ordinary potter's oven without jeopardising the colour. The entire colour scale from bright sulphur yellow to orange can be prepared in these glazes by varying the PbO—Sb_2O_3-content and the earth alkalies and iron oxide-content.

PULSICHROMETER VS. OLD METHOD OF APPLYING GLAZES.—L. M. Munshaw (*J. Amer. Cer. Soc.*, **5**, 827, 1922). The chief advantages are: better production of colours and the elimination of the human element.

OBSERVATION ON FISH-SCALING OF GROUND-COAT ENAMELS.—B. T. Sweely (*J. Amer. Cer. Soc.*, **5**, 618, 1922). According to Danielson and Souder (*J. Amer. Cer. Soc.*, **4**, 620, 1921) the phenomenon of fishscale is intimately connected with compressive stress in the enamel. To test the validity of this idea, the first coat of enamel was removed from a basin by standing 2-300 cc. of conc. HCl in it over night, it being assumed that, if the enamel was in compression, the removal of it from one side of the steel would throw the entire stress upon one coat and produce an exaggerated form of fishscaling. On treating this test piece, the area from which the first coat had been removed on the inside was very sharply defined by the fishscaled area on the outside. This result was shown not to be due to hydrogen-penetration of the steel after the first coat was dissolved. Experiments made by the author indicated that, under factory conditions, any composition, the theoretical coefficient of expansion of which amounts approximately to 400×10^{-7}, will not fishscale.

THE EFFECT OF SOURCES OF PIG IRON UPON THE ENAMELLING OF CAST IRON.—M. E. Manson (*J. Amer. Cer. Soc.*, **5**, 806, 1922). Samples of "northern" and " southern" pig iron were tested. Micrographs are shown of various irons before and after enamelling.

WET PROCESS ENAMELS FOR CAST IRON.—R. N. Danielson and H. P. Reinecker (*J. Amer. Cer. Soc.*, **5**, 647, 1922). An exhaustive study was made of wet process enamels in connection with the use of a ground coat. Dry process compositions were taken as a basis for the work, which included a study of ground coats and white cover enamels. The effect of varying methods of preparing the frits, mill additions, and the relation of composition of the enamels to such properties as adherence, texture and opacity were carefully investigated. *Ground Coats*.—Most of the ground coat frits had to be sintered in order to develop best adherence to the castings. As a mill addition, clay gave best results, flint and felspar being less satisfactory. Excess of clay or flint produced flaking, while felspar tended to develop blistering. About 15% of clay, or 10% each of clay and flint are recommended as mill additions. Excessive additions of any one flux were not desirable; best results were obtained when sodium, lead and boric oxides were combined in more or less definite proportions. Blistering was produced by sodium oxide in excess of about 10%. The firing range of the ground coats was increased by boric oxide, which was therefore preferable to lead, although it tended to promote crawling. *Cover Enamels*.—The mill additions consisted of 5% clay, 8% tin oxide and 45% water. The cover enamel must be adapted to the ground coat in refractoriness. Boric acid increased the firing range, but tended to promote crawling. It also improved the opacity when substituted for such fluxes as sodium and lead oxides. Cryolite increased the opacity, but additions of over 10%, based on the melted weight, tended to promote crawling. The data obtained are tabulated.

COLOURS, DECORATIVE PROCESSES, ETC.

THE CONSTITUTION OF SOME UNDERGLAZE COLOURS.—R. Rieke and W. Paetsch (*Ber. D. K. Ges.*, **3**, 147, 1922). The necessity for intensive calcination of colour mixtures suggests that, in the preparation of the colours,

definite compounds are formed. The authors, therefore, undertook certain investigations, with the object of determining the nature of such compounds, the temperature at which they are formed, and their behaviour under various earthenware glazes. The oxides employed were those most commonly applied, viz. : CuO, Ni_2O_3, Mn_2O_3, Co_2O_3, Fe_2O_3, Cr_2O_3, together with the colourless ZnO and Al_2O_3. With these oxides, three main types of compounds may be formed, namely, chromites, aluminates and ferrites. Two series of mixtures, corresponding to 1 RO : 1 Cr_2O_3 and 4 RO : 1 Cr_2O_3, were prepared in the usual way, fired to 600°, 700°, 800°.....1,350°, and finally treated with conc. HCl. The results (tabulated) demonstrate satisfactorily the formation of well-defined chromites of the type RO : Cr_2O_3 even at low temperatures, the reaction taking place without the addition of any flux, and well below the melting-point of the materials themselves. The compounds thus obtained were then tested for their effect upon various earthenware glazes. Four types of glazes were used for this purpose, and various colours, varying from a greyish-green to pure black, were obtained in the tests. As a general rule, it was found that all the uncalcined mixtures in the proportion 1 RO : 1 Cr_2O_3 differed distinctly from the calcined (chromites). The former invariably exhibited the characteristic greenish shade of the chromium oxide, which is insoluble in the glaze. The chromites, on the other hand, are equally insoluble, and are, therefore, merely suspended in the glaze, to which they consequently impart their characteristic tint.

Similarly, with the uncalcined colours mixed in the proportion of 1 : 4, the green colour again predominates, whilst the same mixtures, after calcination, produced the chromite colour, modified, of course, by the excess of the particular colouring oxide employed.

Similar tests were carried out to demonstrate the formation of aluminates and ferrites, and the following general conclusions are drawn from the results obtained. On calcining mixtures of oxides, containing, as one ingredient, Cr_2O_3, Al_2O_3, or Fe_2O_3, reaction takes place between the components whilst in a solid state, the result being the formation of compounds corresponding to the formula RO : R_2O_3. Of these compounds, which often exhibit characteristic colours, the most stable chemically are the chromites, which are, therefore, most suitable as underglaze colours. The temperature at which the compounds are formed varies with the different materials ; it is particularly low in the case of zinc compounds. Unlike the chromites, the aluminates and ferrites are comparatively easily decomposed or dissolved by the glaze. With regard to the composition of the latter, which naturally plays an important part, it is noted that a high alumina-content is favourable to the use of chromites, whilst a high lead-content has a tendency to decompose these compounds.

Patents.

COMPARING, STANDARDISING, AND TESTING COLOURS.—A. Howland (*Pat. J.*, 1,779, 1923). No. 191,117, Sept. 8, 1921. One or more charts are used in conjunction with a series of rotatable discs comprising variously-coloured sections for determining, reproducing or recording colours in accordance with their luminosity, strength and hue.

DECORATING TEAPOTS, ETC.—W. Lovatt and F. W. Gibson (*Pat. J.*, 1,781, 1923). No. 191,666, Apr. 28, 1922. In decorating pottery, the plaster mould, or part thereof, is constructed with a design in intaglio, to which coloured clay slip is applied, so that this slip becomes attached to the body clay during shaping. That portion of the article bearing the relief pattern, is coated with a different coloured slip to produce a coloured ground, and the raised, coloured pattern is then pared down so as to leave a slightly raised, coloured, clay pattern. The article is then glazed and fired.

Plant and Machinery, Etc.

AN IMPROVED MAGNET BOX.—H. Spurrier (*J. Amer. Cer. Soc.*, **5**, 586, 1922). An instance occurred in actual works practice, in which much trouble was experienced with iron spots in white ware. Several lines were investigated

as probable contributory causes of the trouble, but eventually it was decided that the magnetting process itself required modification. The magnet box had been equipped with malleable iron plates, provided with projections of about $\frac{5}{16}$ of an inch, which were usually submerged beneath the deposit of coarse particles. But since it was known that magnetization was 80 per cent. higher for wrought iron than for malleable iron, the malleable plates were replaced by wrought iron plates. A simple method of measuring the difference in magnetization was worked out, and it was found that an increase of 71 per cent. was possible. A further improvement in the efficiency of the magnet was obtained by arranging a number of fingers at the ends of the wrought iron plates ; the fingers projected upward to a height equivalent to the depth of the slip, and in this way the most powerful part of the magnetic field was carried into the slip itself. In addition, the fingers were "staggered," thus causing the slip to flow in a sinuous course along the magnet box. A complete set of these plates has been in operation for a year, and the results have been highly satisfactory.

AN AUTOMATIC SACK FILLER AND WEIGHER.—(*Südd. Tonind.* **5,** 266, 1923). The apparatus described, produces no dust inoperation, and enables the material to be bagged and weighed simultaneously in any desired weights. These "Bagging scales" can be attached to any silo and are suitable for weighing out all coarse or powdered material, such as lime, plaster, marl, clay, trass, etc. The bag is fixed to the scales by means of a clasp and the machine is then put into operation by simply raising a lever. As soon as the sack has been filled to the desired weight, the supply of material is automatically cut off and the sack is removed.

Patents.

TILE MAKING MACHINE.—W. P. Thompson (*Pat. J.*, 1,788, 1923). No. 193,888, Sept. 24, 1921. Addition to parent Spec. No. 16923/12.

BRICK MOULDING.—Fawcett Ltd., D. L. Fawcett, and A. E. Bottomley (*Pat. J.*, 1,789, 1923). No. 194,539, Mar. 10, 1922. Pusher mechanism is described for delivering clay blanks from a rotating cylinder mould to a press.

MOULDING MACHINE.—E. W. Leigh (*Pat. J.*, 1,791, 1923). No. 195,127, Nov. 25, 1921. Hollow-ware is moulded in a machine comprising a continuously rotating carrier head, which contains a series of moulding cylinders ; these are successively filled with plastic material, which is first compressed to form the base of the article and then extruded on to a cradle to form its wall. It is finally cut off and deposited on a conveyor.

BRICK-MAKING MACHINE.—F. P. Jones (*Pat. J.*, 1,791, 1923). No. 195,280, Apr. 18, 1922. Description of a machine for making bricks with a roughened or antique surface.

POTTERY MAKING MACHINERY.—R. H. Wainford and C. H. Darling (*Pat. J.*, 1,792, 1923). No. 195,445, Dec. 21, 1921. The apparatus described comprises a batting machine, a jigger, and a drying stove combined in such a manner that the progress of the ware boards through the drying stove is determined by, and synchronised with, the operation of the batting machine.

GRINDING APPARATUS.—H. Plauson (*Pat. J.*, 1,793, 1923). No. 195,690, Dec. 5, 1921. In dry grinding solid materials to particles of diam. less than 0·008 mm., the dry material is ground at very high speed in vacuo until a substantial part is of the desired fineness. The material may be treated with a small quantity of a dispersator to accelerate the process. The apparatus is described.

BRICK MACHINES ; DIES.—J. Harrison and H. Beebe (*Pat. J.*, 1,794, 1923). No. 196,234, Jan. 20, 1922. An arrangement of a lubricating die is described.

III.—FINISHED PRODUCTS: TESTING, ETC.

THE TRANSLUCENCY OF PORCELAIN.—W. Steger (*Ber. D. K. Ges.*, **3**, 50, 1922). The effect of substituting German quartz sand for Scandinavian quartz in the manufacture of porcelain was investigated by the author. In his experiments, he used washed china clay of the Zettlitz variety, ground Norwegian felspar, and the following quartz materials : (*a*) quartz sand (from Hohenbocka), (*b*) Norwegian quartz, and (*c*) geyserite from the Taunus. The translucency of the specimens was tested by the method outlined in a previous paper (TRANS. **21**, 54 (A), 1922). For testing purposes, plates 3 cm. square were carefully prepared, fired in a works oven to cone 15, and then ground down to exactly 3 mm. thickness. From the tabulated results, the following conclusions are drawn : (1) under normal conditions of composition, grain size of the silica raw materials, low clay-substance content (40%) and a sufficiently high firing temperature—cone 15—,porcelain bodies made with Norwegian quartz are three times more translucent than those made with (German) quartz sand or with geyserite ; (2) under the same conditions, but with a clay-substance content of 50%, the porcelain made with Norwegian quartz is twice as translucent as the quartz sand body, while Taunus geyserite, reduces the translucency to one-half that of the quartz sand body.

IMPACT TESTS ON TABLEWARE.—H. H. Sortwell (*J. Amer. Cer. Soc.*, **6**, 349, 1923). A summary of the results of impact tests, carried out at the American Bureau of Standards, is as follows : The tests were applied to sets of plates in six thicknesses covering the range from $\frac{1}{8}$ to $\frac{3}{8}$ inch ; the plates were supplied by five potteries, three making semi-porcelain and two vitrified china. The plates were struck in the centre, and both "starring" (any failure of glaze or body) and complete fracture were observed. It was found that, in all the types tested, the impact required to cause "starring" increased with the thickness in an approximately parabolic relation corresponding to $y = 3x^{1\,236}$, in which y is the impact energy in foot-pounds and x the thickness of the plate. Increase in the thickness of plain, semi-porcelain, household plates, within commercial ranges, had no appreciable effect on the impact causing complete fracture of the plate. In double-thick semi-porcelain hotel plates the ultimate impact strength increased irregularly with increase in thickness, and the blow causing failure was much heavier than for the other types of plates tested, owing to the bracing effect of the very thick rim. The impact causing complete failure of vitrified china hotel plates did not appear to vary regularly with the thickness. The results indicate that, in comparing results of impact tests of this kind on plain and rolled-edge commercial plates, small variations in thickness may be ignored.

BRICKS USED FOR ELECTRIC FURNACES.—C. Campbell (*Brick Pot. Tr. J.*, **31**, 165, 1923). *Firebricks* are not usually so sensitive to changes of temp. as silica bricks. The danger due to shrinkage is liable to become a serious factor when firebricks are used for furnace roofs, though, if correctly manufactured, they will give satisfaction. *Half-silica* bricks, prepared from a mixture of quartz and burnt clay in varying proportions, are therefore likely to supercede most others for furnace roof construction. *Silica bricks* are very largely used at present in the construction of roofs. The mortar used consists principally of white silica sand with a little fireclay. The finished brick should contain at least 95% silica, with 1–2% lime as binding agent. Silica brick roofs can be made with almost flat arches, owing to the expansion of the bricks with a rise of temp. *Dolomite bricks* are largely used for lining the bed and walls of most electric furnaces. The raw dolomite is crushed to small pieces, burnt to clinker in a shaft furnace, and about 20% of coke is added. The mass is then ground in a pan mill and mixed with about 10% of pure tar. *Magnesite bricks* are frequently used for that part of the lining which is in direct contact with the charge. Magnesite is highly resistant ot the action of slag and limestone, and is said to be more neutral in character than dolomite. *Chromite* is used at that part of the furnace where the acid and basic linings meet, *i.e.*, where the roof touches the walls.

CHROME REFRACTORIES.—J. S. McDowell and H. S. Robertson (*J. Amer. Cer. Soc.*, **5**, 865, 1922). The paper is compiled from the available literature and gives the more important data on chromite and chrome refractories. A full bibliography is appended.

BRICKS FOR MUFFLE FURNACES.—(*Brit. Claywr.*, **32**, 41, 1923). The requisite qualities of the bricks are discussed under the following heads:—temperature, strength when hot, changes of temperature, corrosion, thermal conductivity, and constancy of volume.

TERRA-COTTA.—A. P. G. (*Brit. Claywr.*, **32**, VI. [*Brick Builder*], 1923). The advantages of terra-cotta as a building material are pointed out. Its superiority over concrete, Bath or Portland stone, and Italian marble was established by the flame-and-water test.

WHITE SCUM ON BRICK WORK.—(*Deut. Töp. Zieg. Ztg.*, **54**, 144, 1923). The white scum appearing on brickwork is not always due to the raw materials used in making the bricks. Instances are cited in which the trouble was due (*a*) to storing the bricks in unsuitable places on the building site; (*b*) to the use of impure water, or unsuitable materials for mixing the mortar; (*c*) to insufficient protection of the brickwork from external (ground, etc.) influences.

COMPARISON OF HOT AND COLD MODULUS OF RUPTURE FOR SILICA BRICKS.—E. N. McGee (*J. Amer. Cer. Soc.*, **5**, 888, 1922). In America it has now become common practice to use silica bricks in nearly all parts of the coke oven. The principal advantage obtained from the use of silica bricks lies in the higher temperature at which the ovens can be operated, resulting in a much faster coking rate, and, consequently, a much greater yield of coke and gas. The reason for these results is not because the silica bricks are more refractory, nor are they due entirely to a higher thermal conductivity; the chief characteristic of silica bricks, rendering them so valuable to the coke oven industry, is their ability to carry heavy loads at very high temperatures.

When subjected to a load of 25 lb. per sq. in., the best clay bricks exhibit deformation at 1,350°C. If supported on other bricks at both ends, with seven inches clear, and loaded with a five-pound brick in the centre, and subjected to a temp. of 1,450°, they show a bending of from $\frac{1}{4}$ to $\frac{3}{8}$ inch. On the other hand, silica bricks show no deformation at 1,350° under a load of 50 lb per sq. in. and no bending on any test which has yet been made.

The main object of this investigation was to determine whether, or not, the hot and cold strengths of silica bricks give comparative values. A second purpose of the work was to obtain relative values for the cross-breaking strength of the bricks at temperatures encountered in coke oven practice. The tests were made on a series of bricks obtained from a well-known manufacturer. They were bricks of a special type and consequently uniform in every way.

From the results of the tests it was concluded that, although no definite conclusion regarding the relation of the hot modulus of rupture to the cold crushing strength could be drawn, yet some useful deductions might be made. The cross-breaking strength of a brick at 1,350° is approximately one-third the strength at atmospheric temperature. For the series in question, it averaged from 130 to 189 lb. per sq. in. The investigation also showed that too rapid or erratic heating of silica bricks up to red heat may cause such weakening of the structure or bond that they will break under very low pressures. The cross-breaking strength decreases as the temperature rises. In general, the hot modulus of rupture tests appeared to give results comparable in most respects with the cold test, and for routine work the latter test, which can be made in a much shorter time, would seem to give a fair indication of what can be expected in actual practice.

A REMARKABLE CAUSE OF THE FAILURE OF A COKE-OVEN WALL.—M. Pulfrich (*Tonind. Ztg.*, **47**, 271, 1923). By the application of optical petrographic methods of testing refractories, the existing manu-

facturing processes have been extended and placed on a more secure foundation. With the aid of the polarising microscope it is now possible, in testing silica bricks, for instance, to supplement the results of chemical analysis and physical tests (volume changes, etc.) to such an extent that reliable conclusions as to the properties of the brick may be drawn. But the optical test is not intended to replace the others. The experience described in the present paper is given as an example in which the methods previously applied proved inadequate, and in which the solution of the mystery was due entirely to microscopical investigation.

A silica brick, which had proved unsatisfactory in practice, leading to crumbling of the oven walls was sent to the laboratory to be tested. The chemical analysis gave : 0·10% loss on ignition, 94·54% silica, 3·45% alumina, 0·34% iron oxide, and 1·58% calcium oxide. In refractoriness, the sample corresponded to cone 35, so that, as regards both chemical composition and refractoriness, there appeared to be no grounds for complaint. From these results it was naturally to be assumed that the quartzite employed was either unsuitable, or had undergone insufficient modification during the firing of the brick. Microscopical examination in thin section showed, however, that the quartzite in the brick had undergone complete modification, and that partial formation of tridymite had taken place. It was, therefore, concluded that the bricks must have withstood several firings in the coke oven before collapsing, and, upon enquiry, this assumption was confirmed ; the bricks had, in fact, done over one year's service in a coke oven.

A sample of the silica cement used in laying the bricks was next examined. Chemical analysis gave : 0·48 per cent. loss on ignition, 86·60% silica, 9·54% alumina 0·56% iron oxide and 0·20% calcium oxide, while the refractoriness corresponded to cone 33. These results were considered as quite normal ; and since the cement, like the bricks, had been in service for over a year, no solution of the difficulty appeared possible on the basis of the usual chemical and physical tests. A clue might possibly have been afforded by the determination of the specific gravity which, for the used cement, was 2·58. However, when magnified 33 times under the polarizing microscope, the quartz in the cement was observed to be only in the initial stages of transformation. The cause of the crumbling wall was, therefore, due to the consequent expansion of the quartz, which amounts, theoretically, to 14% during transformation.

NOTE ON LADLE BRICKS.—D. A. Moulton (*J. Amer. Cer. Soc.*, **5**, 823, 1922). The lining of ladles used for transporting molten metal from a blast furnace consists, in America, of bricks covered with a rammed mud cake made of six parts of fire-brick grog, two parts clay and two parts silica stone. This cake will last 48 hours continuous use and comes out with the "skull" (J. W. Haulman, *Blast Furnace and Steel Plant*, **5**, 159, 1917). In an English ladle on the other hand, four or five chemical reactions occur simultaneously, viz. : oxidation, deoxidation, colloidal segregation, cooling, and definite change of phase (skull formation). One hundred grains of such a brick gave off only 2·45 cc. of gas at 767 mm. at 15°C. (*cf.* A. Reynolds, TRANS., **17**, 385, 1918). The fusion point of ladle bricks ranges from cone 17 to cone 30, depending upon the behaviour of the clay at temperatures below the fusion point. As many as 1,000 heats can be obtained with a brick lining when the rammed clay lining is used to protect the bricks. The best ladle bricks have a fusion point of cone 26, and are made without the addition of any sandy material. Bricks made by the dry-press method have given best results in practice.

It has been found that the standard tests for refractories, particularly the slag test, are too severe for ladle bricks, and it is, therefore, suggested that special tests for this particular type of refractory should be worked out.

SOME NOVELTIES IN THE CHEMICAL STONEWARE INDUSTRY.—M. Kaltenbach (*Chim. Ind.*, **9**, 227, 1923). Some special uses, to which stoneware is now being put in the chemical industry, are briefly described. The apparatus illustrated include stoneware casings for fans, hand and motor pumps, control stopcocks, and Raschig rings.

THE EFFECTIVENESS OF DIFFERENT METHODS OF MAKING ABSORPTION DETERMINATIONS AS APPLIED TO HOLLOW BUILDING TILES.—H. D. Foster (*J. Amer. Cer. Soc.*, **5**, 788, 1922). Specimen hollow tiles from 17 sources were (1) immersed in water at room temp. for various periods ranging from 15 min. to 9 days; (2) boiled for various periods ranging from 1 to 5 hours and then cooled in water at room temp. for at least 1 hour, and (3) subjected to repeated vacuum treatment. The true porosity was then obtained from the specific gravity and the percentage saturation reached by the various methods was calculated. The results show that the five-hour boiling treatment gives a figure 1·28 greater for an average of all the tiles than the 72-hours immersion in cold water. The cold water immersion treatment gave 73·5% saturation, the boiling treatment 92·7%, and the vacuum treatment 97·0%. In general, it is concluded, the most convenient and practical way of determining the absorption of hollow tiles is by boiling for 5 hours and then cooling for at least 1 hour before the saturated weight is taken.

THE EFFECT OF SOME FLUXES ON THE ABSORPTION AND TRANSVERSE STRENGTH OF A TERRA COTTA BODY.—E. C. Hill (*J. Amer. Cer. Soc.*, **5**, 832, 1922). A short series of tests was made to lower the absorption and increase the strength of terra cotta by the use of the following common materials: (1) felspar—could be used in amounts from 5 to 10%; (2) Albany slip—less effective than felspar, darkens the colour and increases drying shrinkage; (3) powdered glass—somewhat more effective than felspar, appears to offer greatest possibilities if it could be obtained at a moderate price; (4) white lead—not very active, and too expensive; (5) cryolite—effective but too expensive; (6) whiting and fluorspar—up to 5% whiting increases absorption, but does not lower the strength, while fluorspar increases absorption and lowers the strength; (7) magnesium carbonate—increases absorption and lowers the strength; (8) furnace slag—addition of 10% ground to pass a 40-mesh sieve lowered absorption, but did not increase the strength.

IV.—MANAGEMENT, ORGANISATION, COSTING, ETC.: COMMERCIAL.

THE CONTROL OF BISCUIT LOSSES.—I. E. Sproat (*J. Amer. Cer. Soc.*, **5**, 588, 1922). The most important factor affecting the biscuit losses is probably the "human element." In an investigation carried out during 1919, in America, a number of different methods were tried, the following three-fold control being finally decided upon: (1) Transverse strength of body in the clay state; (2) Biscuit loss analysis, and (3) Analysis of crushers' report. The transverse strength of the body in the clay state is a very important factor in the control of biscuit losses. If the modulus of rupture is maintained at 280 lb. per sq. in., the effect of careless handling of the ware is offset, and the human element to some extent controlled. It was found, for instance, that the biscuit losses decreased with every marked increase in strength up to 300 pounds, and *vice versa*. The effect of the human element is also rendered less prominent if the ware is not taken off the moulds until it is bone dry. The method adopted for analysing the damaged ware from the kilns must meet the following three requirements:—(1) It must not require much time, as it is advisable to analyse at least one class of ware daily: (2) the analysis should be made on that class of ware, which passes through the kiln in large quantities, and in which biscuit losses are heaviest, *e.g.*, seven-inch plates; (3) the various types of damages must be classified carefully. With regard to the third point, the following classification of faults is suggested, the cause of the fault being indicated in brackets: (1) Nipped—*i.e.*, not cracked or warped (careless handling); (2) Warped—(too high ball-clay content, too high or rapid firing); (3) Rim cracked—when the crack is wider at the rim than in any other portion (body too weak; careless

handling) ; (4) Foot cracks—(as for 3) ; (5) Bottom cracked—(as for 3 and 4) ; (6) Dunted—fine, circular, hair line cracks with smooth surface (too rapid cooling); (7) Sympathetic dunts—similar cracks as in 6, but the entire surface of the cracked portion is not smooth (too weak body, poor pugging, occluded air, careless handling). The figures obtained in each of these seven groups are compared with normal percentages, obtained by inspecting (in this instance) 10,000 damaged plates taken from burns in which the losses were normal. The data obtained from daily analyses of this kind would be of great value in giving timely warning of such troubles as : too weak a body, careless handling, improper firing, or too rapid cooling of the kilns. Special losses such as edge cracks, cup handles coming off, etc., can best be detected and controlled by an analysis of the crushers' report. But unless the percentage of loss of all damaged ware is figured each day, it is useless as a guide for control. All damaged ware sorted out one day should be ready for inspection on the following day, so that, if a given class of ware shows an abnormal loss, the damaged ware is available for inspection and study.

FIRECLAY REFRACTORIES FOR THE STEEL INDUSTRY.—C. L. T. Edwards (*Blast Fur.*, **11**, 100, 1923). The writer has had practical experience both in the steel and in the refractory industry, and the main object of his paper is to bring about better co-operation between maker and consumer of fireclay products, by explaining, in general terms, the difficulties of the one to the other.

TERRA COTTA PROBLEMS SUGGESTED FOR DISCUSSION AND INVESTIGATION.—C. W. Hill (*J. Amer. Cer. Soc.*, **5**, 732, 1922). The following subjects are suggested :—(1) plaster ; (2) materials ; (*a*) body mixtures and materials, (*b*) barytes, (*c*) grog ; (3) glaze ; (4) processes ; (5) patching ; (6) service problems.

MANUFACTURING CLAY PRODUCTS 14,000 FEET ABOVE SEA LEVEL.—E. O. King (*J. Amer. Cer. Soc.*, **5**, 739, 1922). A description is given of the clays and methods employed by an American company in the Andes for the manufacture of common and refractory bricks.

V.—GLASS: GENERAL.

NOTE ON ANOMALIES IN THE EXPANSION OF GLASSES.—P. Lafon (*Verre*, **3**, 54, 1923). The reversible and irreversible anomalies are discussed.

THE VALUE OF GAS ANALYSES IN GLASS WORKS.—(*Sprech.*, **56**, 228, 1923). The composition of the gases of combustion is discussed. Every one per cent. of CO in these gases means a loss in heating value of more than 4%. The Orsat apparatus is discussed.

ACCURATE GLASS TUBES.—(*Chem. Age*, **8**, 615, 1923). The German "Küpper" process obviates the difficulty of having to gauge each tube or flasks separately, by inserting a cylindrical metal core into the drawn glass tube, evacuating the tube, and slowly heating up from the outside. When the glass becomes soft, the atmospheric pressure forces the glass walls into intimate contact with the metal core. Tubes of square or tapered bore can also be made by this process.

A COMPARATIVE STUDY OF THE LABORATORY GLASS MADE IN FRANCE, ENGLAND, GERMANY AND AUSTRIA.—P. Nicolardot (*Chim. Ind.*, **9**, 233, 1923). The glasses were tested for their resistance to (1) water at various temperatures, and under pressure, and (2) the more commonly employed alkaline, neutral and acid reagents. The results are tabulated.

THE WEATHERING OF GLASS CONTAINERS.—K. L. Ford (*J. Amer. Cer. Soc.*, **5**, 837, 1922). The importance of stability in storage of commercial glass and the means of reducing the tendency to weather are discussed. Three

types of weathering effects are distinguished and these are illustrated by microphotographs. Continued boiling removed the weathered surface. The products of weathering consist of crystals of soluble salts, mainly sodium carbonate, and an insoluble film. The lime, soda and silica are present in the same proportions in the weathered material as in the original glass, with the addition of certain quantities of carbonate, moisture, dirt and organic material. Weathering is largely dependent upon solubility; glass showing the greatest resistance to weathering proves equally resistant to the action of water at temperatures and pressures above normal. Alumina increases resistance to weathering; sodium carbonate may exist in glass after manufacture and assist in weathering.

SOME OBSERVATIONS ON THE MIXING OF GLASS BATCHES IN FACTORIES.—A. W. Dickenson, V. Dimbleby, L. E. Norton and W. E. S. Turner (*J. Soc. Glass Tech.*, **6**, 234, 1922). Observations made over a period of some years in actual glassworks practice are recorded. Certain principles underlying the mixing of the batch are first discussed, such as the weighing or measuring of batch materials and the apparent swelling of sand when wet. This is followed by an account of investigations on ten actual works batches. The results are tabulated.

NOTE ON THE EFFECT ON MANGANESE IN GLASS MELTED UNDER REDUCED PRESSURE.—E. N. Bunting (*J. Amer. Cer. Soc.*, **5**, 594, 1922). The decolorizing action of manganese is destroyed by melting and firing glass at 1,400° under a pressure of 0·03 atm., the Mn_2O_3 being decomposed into MnO and O_2. The ordinary light green colour was produced by firing glass in an electric furnace, in which the pressure could be gradually reduced. In one experiment, the winding burned out, leaving the firing incomplete, with the pressure at 0·03 atm. It was noted, on turning out the pot, that the bottom 5 cm. of glass was coloured light green, the mid section of 5 cm. was colourless, while the top 2 cm. were pink. The green section was free from bubbles, the mid-section contained many fine ones, and in the pink layer there were more bubbles than glass. The latter was probably due to the high O_2-content of the gas in the bubbles, which oxidised some of the MnO to Mn_2O_3. The glass contained 0·2% MnO and the manganese content of the three layers was the same.

NEW DATA IN THE HISTORY OF SILESIAN GLASS MANUFACTURE.—F. Kaminsky (*Sprech.*, **56**, 144, 1923).

SOME PRACTICAL NOTES ON THE MANUFACTURE OF COLOURLESS GLASS IN A TANK FURNACE.—F. W. Adams (*J. Soc. Glass Tech.*, **6**, 205, 1922). Colourless glass is gradually replacing green glass for food containers, etc. It is purer, and therefore more costly to make. The general conditions necessary for the successful operation of a colourless glass producing plant are discussed. The *tank* must be sufficiently long and deep, for melting and firing to be complete before the metal passes through the doghole. The nose of the furnace must be large enough to allow the metal to settle and become uniform as regards viscosity. With regard to the quality of the *tank blocks*, it may generally be taken that the higher the soda-content of the batch, the higher should be the alumina-content of the block. A fairly close block, of the following composition, stood very well: SiO_2 58·9, Al_2O_3 37·58, Fe_2O_3 1·71, CaO 0·54, MgO 0·47, Na_2O 0·36, K_2O 0·84. *The batch.* Mechanical mixing is advisable, as the amounts of decoloriser added are so small. Regular chemical tests should be made both on the batch and on the finished metal. The functions of manganese dioxide and selenium as decolorisers are discussed. To obtain consistently good results, the following points must receive attention: (1) complete analyses should be made of all batch materials, especially of the decoloriser; (2) the total iron content of the finished glass must be kept constant; (3) the batch ingredients must be carefully weighed and thoroughly mixed; (4) the charging of the furnace with batch should be regular; (5) pyrometers should be used to ensure a constant melting temperature; and (6) the correct annealing temperature

should be maintained in the lehr, for which purpose it is advisable to instal at least two pyrometer stations.

THE COMPOSITION OF LIME SUITABLE FOR VARIOUS PURPOSES IN GLASS-MAKING.—V. Dimbleby and W. E. S. Turner (*J. Soc. Glass Tech.*, **6**, 221, 1922). Discussing the Provisional Specification for limestone to be used in glass manufacture, recently published by the American Bureau of Standards, the authors suggest that it is advisable for the manufacturer to engage a technologist to control his raw materials, rather than to work to a stereotyped specification. Of the five possible impurities mentioned in the specification, silica, alumina, sulphuric and phosphoric anhydrides are not necessarily harmful. On the other hand, the amount of iron oxide present in a colourless glass, made in a tank furnace and decolorised by selenium, must not exceed 0·09%. With this point in view, the authors indicate the principles on which limestone or limespar should be selected. Iron oxide finds its way into the batch not only from the raw materials, but also from the cullet and from the furnace itself. As much as 0·03% may be derived from the last source. Figures are tabulated to show the degree of purity which limespar or limestone must have in different circumstances, the figures being calculated in terms of the maximum amount of iron oxide allowable. The analyses of a number of limestones and limespars, now available for glass-making, are also given in three additional tables.

THE DENSITY OF THE SODA-LIME MAGNESIA GLASSES AND SOME OBSERVATIONS ON THE CALCULATION OF DENSITY.—S. English and W. E. S.Turner (*J. Soc. Glass Tech.*, **6**, 228, 1922).

ON THE DEVITRIFICATION CAUSED UPON THE SURFACE OF SHEET GLASS BY HEAT.—Y. Amenomiya (*J. Soc. Glass Tech.*, **6**, 231, 1922). See TRANS., **21**, 133 A, 1922.

PATENTS.

MAKING ARTICLES OF FUSED SILICA.—British Thompson Houston Co. (*Pat. J.*, 1,788, 1923). No. 194,092, Jan. 31, 1922. A furnace is described in which articles of fused silica, having a glazed external surface, are made.

MAKING GLASS BOTTLES.—T. Dodds (*Pat. J.*, 1,788, 1923). No. 194,203, May 11, 1922. Relates to the manufacture by machine of glass bottles, having a rough interior surface.

GLASS ROLLING MACHINERY.—Chance Bros. and A. L. Forster (*Pat. J.*, 1,789, 1923). No. 194,441, Dec. 23, 1921. In the machinery described, means are provided for dividing the sheet into plates of required lengths and for imparting an additional forward or accelerated movement to the receiving table each time a cut is made, in order to carry the plate clear of the succeeding plate.

DRAWING GLASS.—Libbey Owens Sheet Glass Co. (*Pat. J.*, 1,789, 1923). No. 194,567, Apr. 4, 1922. By means of a heating element, consisting of a bar of refractory material, situated in the mass of the glass, the temperature of the molten glass, which is to constitute the inner part of the sheet, is raised.

AUTOMATIC FEEDER.—K. E. Peiler (*Pat. J.*, 1,789, 1923). No. 194,675, Feb. 13, 1923.

GLASS CRUCIBLE FURNACE.—T. Teisen (*Pat. J.*, 1,790, 1923). No. 194,819, Dec. 22, 1921. An arrangement is illustrated by which leakage of spilt glass into the recuperators is prevented by a system of cooling-passages.

GLASS DECOLORISER.—Corning Glass Works (*Pat. J.*, 1,790, 1923). No. 194,888, Feb. 7, 1922. A decoloriser for borosilicate glass consists of neodymium oxide. About 0·5—1% of Nd_2O_3 is added to the batch to neutralise the yellow green tint. The commercial product known as "didymium oxide," a mixture of neodymium and lanthanum oxide, is used. The addition of 5% of Nd_2O_3 produces a pink colour.

BLOWING MACHINE.—Corning Glass Works (*Pat. J.*, 1,790, 1923). No. 194,889, Feb. 7, 1922. Means are provided for actuating the air pump in such a manner as to give the initial puff to the parison.

AUTOMATIC FEEDING DEVICE.—K. E. Peiler (*Pat. J.*, 1,791, 1923) No. 195,376, Mar. 19, 1923. The device described delivers charges of molten glass of different predetermined weights in regular succession.

DELIVERING MOLTEN GLASS.—H. H. Pitt (*Pat. J.*, 1,792, 1923). No. 195,448, Dec. 29, 1921. A feeder for delivering gathers of molten glass to a forming machine is described.

MAKING TRANSLUCENT OR OPAQUE GLASS.—Corning Glass Works (*Pat. J.*, 1,792, 1923). No. 195,495, Feb. 7, 1922. A batch containing boric oxide, a relatively high percentage of silica, and a chloride, bromide, or sulphate is melted. The boric acid content should not be less then the alkali content, and the silica should be over 70% of the ingredients other than the chloride, etc. In practice, 1 to 5 parts of a chloride, bromide or sulphate of an alkali metal are added to 100 parts of a suitable foundation batch.

MAKING BUBBLE-FREE SILICA GLASS.—British Thomson-Houston Co. (*Pat. J.*, 1,792, 1923). No. 195,508, Mar. 8, 1922. Bubble-free, transparent silica glass is made by heating a mass of crystalline quartz to the fusing temp. while mechanically supporting the mass. Fusion is carried out in an electric vacuum furnace.

DRAWING SHEET GLASS.—Libbey Owens Sheet Glass Co. (*Pat. J.*, 1,794, 1923). No. 196,175, Apr. 4, 1922. A device is described for drawing sheet glass, by means of which the external faces of the meniscus at the base of the sheet are heated in order to avoid wavyness of the surface of the sheet.

MAKING SHEET GLASS.—C. W. Avery and E. T. Brown (*Pat. J.*, 1,795, 1923). No. 196,293, 12 Apr., 1923. A process of producing sheet glass in a continuous strip is described.

MOULDING GLASS BY CENTRIFUGAL FORCE; POLISHING.—Corning Glass Works (*Pat. J.*, 1,796, 1923). No. 196,722, Feb. 7, 1922. A method of finishing glassware, particularly for flanging and lipping beakers, consists in heating the portion to be finished and rotating the article at such a velocity that the heated portion is forced to conform to the shape of a former.

COATING GLASS.—British Thomson-Houston Co. (*Pat. J.*, 1,796, 1923). No. 196,843, June 21, 1922. A coating process, adapted to replace sand-blasting, consists in spraying on a composition containing talc, French chalk, or zinc oxide, or a mixture of these and alkaline silicate solution. Apparatus for carrying out the process in connection with electric lamps is shown diagrammatically.

VI.—CEMENT, CONCRETE, MORTARS, ETC.

MODERN FERRO-CONCRETE CHIMNEYS.—P. Frei (*Tonind. Ztg.*, **47**, 367, 1923). The monolithic method of construction has now given place to the modern block structure. Some block shapes are illustrated.

CONCRETE BOILING PANS FOR SALT WORKS.—B. Block (*Tonind. Ztg.*, **47**, 393, 1923). Pans 40 metres long and 4 metres wide are illustrated and described. Iron pipes, which are heated by waste heat from boilers, etc., are suspended within the pans.

HOW TO BUILD BETTER CONCRETE ROADS.—Various authors (*Concrete*, **22**, 3, 1923).

DESIGN OF CONCRETE MIXTURES.—F. S. Besson (*Concrete*, **22**, 10, 1923). The possibility of predetermining the strength of concrete is discussed, more complete use of present knowledge of the factors influencing quality being advocated. The subjected is treated mainly from the point of view

of concrete for road making.

CIMENT FONDU, OR ALCEMENT.—K. Christiani (*Concrete*, **22**, 25, 1923). An account is given of the properties of the French ciment fondu, or ciment électrique, both of which are called alcement in Danish. Comparative figures are tabulated for ordinary Portland cement and for ciment fondu showing the results of compression, tension and driving tests.

THE CAUSTIC CALCINATION OF DOLOMITE AND ITS USE IN SORREL CEMENTS.—G. A. Bole and J. B. Shaw (*J. Amer. Cer. Soc.*, **5**, 817, 1922). A method is described by which dolomites can be calcined in such a way as to liberate the magnesium oxide and have the calcium carbonate undecomposed by controlling the pressure of the carbon dioxide. Dolomite having practically the same composition may differ radically in physical constitution, the explanation offered being that some dolomites are solid solutions, some double salts, and others mixtures of these two. The best temp. for calcining ore to be used in sorrel cement was found to be approx. 725—750°C. Ores high in silica make an inferior cement. Dissociation, tensile strength, volume change, time of set and weather test data are given.

TESTING OF CONCRETE BUILDING UNITS.—J. C. Pinney (*Cement Eng. News*, **34**, No. 4, 32, 1923). A general discussion on the value and importance of laboratory tests to modern industry.

THE MORTAR OF THE ABU ROASH PYRAMID.—M. v. Glasenapp (*Tonind. Ztg.*, **47**, 361, 1923). The mortar was subjected to chemical and optical tests. The chem. anal. gave: 31·7% CaO, 0·1% MgO, 2·0% Al_2O_3+ Fe_2O_3, 38·46 SiO_2, 23·31% loss in ignition, including 3·75 CO_2, 3·8% soluble in HCl.

DEVELOPMENTS IN SURFACE-TREATED CONCRETE.—R. F. Havlik (*Concrete*, **22**, 83, 1923). The surface of concrete products may be treated by (*a*) grinding with carborundum wheels in special machines; (*b*) spraying with water under pressure, or (*c*) scrubbing with muriatic acid and water. These methods are described. The method of making plaster and glue moulds is also illustrated and described.

THE MANUFACTURE OF FORMS FOR CONCRETE STAIRS.—W. F. Lockhardt (*Concrete*, **22**, 89, 1923).

"ALCA" CEMENT.—H. S. Spackman (*Concrete*, **22**, *Mill Sect.*, 35, 1923). The composition of the French cements (ciment fondu, ciment électrique, etc.) now being put on the market, ranges within the following limits: lime 35—45%; alumina 35—45%; iron oxide 5—12%, and silica 5—12%. In the newer French and Swiss plants, fusion is done in electric furnaces.

Patents.

SLOW-SETTING CEMENT.—H. Koutzler (*Pat. J.*, 1,787, 1923). No. 193,372, Aug. 1, 1922. An intimate mixture of gypsum with aluminates, hydrates of alumina such as bauxite, natural or artificial puzzuolanas, *e.g.*, blast-furnace slag, is pulverized finely to produce a slow-setting cement.

FIRE-AND-WATER-PROOFING CONCRETES.—F. Guy and M. L. Davey (*Pat. J.*, 1,788, 1923). No. 193,829, Jan. 30, 1923. A fire-proofing, or water-proofing composition, to be added to concretes, is prepared as follows: one part commercial soap, containing 10% sodium silicate, is dissolved in 1½ parts hot water, and 3 parts of sand are added. The mixture is allowed to set, ground, and mixed with ground alum in the propertion of 2 : 1 for water-proofing, and 1 : 1 for fire-proofing. From 1 to 1½ lb. of the composition are added per cu. ft. to the concrete before moulding.

ARTIFICIAL STONE.—L. Morin and F. Gounder (*Pat. J.*, 1,788, 1923). No. 193,978, Dec. 5, 1921. To a fused vitreous mass, obtained by fusing a mixture of sand, fluorspar, felspar and cryolite, a refractory substance (quartz, crystallised alumina, magnesia, etc.) is added in such quantity that the mass is devitrified, some of the refractory substance remaining undiscolored.

BUILDING MATERIALS.—H. Grönroos (*Pat. J.*, 1,788, 1923). No. 194,264, Jan. 19, 1923. Building-blocks are made by mixing 400 parts by weight of slag or the like, 100 parts glass refuse, 100 parts clay, 1 part iron oxide, 5 parts saltpetre, and 2 parts quartz, rendering the mixture plastic with water, moulding under pressure, and firing at about 740°C. For paving-slabs the above proportions of slag and glass are reversed.

PAVING BLOCKS.—F. Morton (*Pat. J.*, 1,789, 1923). No. 194,448, Jan. 4, 1922. A composition for blocks consists of 70—75 parts by weight of blast furnace or coal tar pitch, 20—25 parts hardwood sawdust, with, or without, 3 parts of fine sand or grit and 10 parts rubber.

CONCRETE AND MORTARS.—R. C. Williams (*Pat. J.*, 1,789, 1923). No. 194,526, Feb. 27, 1922. The compositions given contain silica stone or sand stone, lime and an agglutinant.

STEAM-HEATED FILM DRYER FOR CEMENT SLURRY.—T. Rigby *Pat. J.*, 1,790, 1923). No. 194,738, Sept. 16, 1921.

ROTARY FURNACES FOR CALCINING CEMENT.—I. E. Lanhoffer (*Pat. J.*, 1,792, 1923). No. 195,585, July 12, 1922. In a two-section furnace, a portion of the gases from the high-temp. section is utilised to remove dust from, and to heat the material passing from the low to the high-temp. section.

COOLING CEMENT.—I. E. Lanhoffer (*Pat. J.*, 1,792, 1923). No. 195,612, July 12, 1922. An auxiliary rotary cooling-chamber for a cement kiln is lined with a series of overlapping plates, which support the clinker and form passages for the supply of cooling air.

CONCRETE MIXING MACHINE.—Parker, Winder and Achurch, and G. P. Achurch (*Pat. J.*, 1,793, 1923). No. 195,881, May 10, 1922.

CONCRETE STAMPING PRESS.—P. J. White (*Pat. J.*, 1,795, 1923). No. 196,404, Jan. 30, 1922. Relates to a press for making hollow concrete blocks.

CONCRETE MOULDING MACHINE.—W. G. Bailey (*Pat. J.*, 1,795, 1923). No. 196,484, May 3, 1922. A machine for moulding concrete blocks is described.

VII.—CHEMICAL AND ANALYTICAL PROCESSES.

ALTERATION OF SILICATES BY SONSTADT'S SOLUTION.—T. L. Walker (*Amer. Mineralogist*, **7**, 100, 1922). The substitution of potash for soda on treating silicates with Sonstadt's mercuric-potassic-iodide solution is briefly discussed.

THE APPLICATION OF COLLOID CHEMISTRY TO MINERALOGY AND PETROLOGY.—A. Scott (*Colloid Chemistry and its Industrial Applications*, **4**, 204, 1922).

INDUSTRIAL APPLICATIONS OF THE COLLOID MILL.—S. P. Schotz (*Chem. Age*, **7**, 493, 1922). The article discusses the possibilities of the Plauson mill in the varnish and other industries.

DETERMINATION OF SILICA IN FILTERED SEA-WATER.—R. C. Wells (*J. Amer. Soc.*, **44**, 2,187, 1922). A method is outlined and some results for the determination of soluble silica in sea water are given.

THE INDUSTRIAL APPLICATIONS OF ELECTRO-OSMOSIS.—J. H. Fnydlender (*Rev. Prod. Chim.*, **25**, 721, 1922). A résumé of the literature on the subject. A section on the purification of clay and kaolin is included.

RAPID DETERMINATION OF IRON OXIDE AND ALUMINA IN LIME MARL AND ITS FIRED PRODUCTS.—F. Lucchesi (*Giorn. Chim.* **5**, 14, 1923). The precipitated hydrates of Al and Fe, obtained with ammonia in the presence of ammonium chloride, are dissolved in $N/2$ H_2SO_4. The excess of acid is then titrated with $N/2$ NaOH, using methylorange as indicator. By difference, the amount of H_2SO_4 combined with the oxides of Al and Fe can then be determined. After adding conc. H_2SO_4 and reducing with H_2S, the ferric oxide is estimated in the usual way with $N/10$ KMn O_4, and from the result, the quantity of $N/2$ H_2SO_4 combined with the ferric oxide is calculated, the alumina being then estimated by difference.

THE LAW OF DISTRIBUTION OF PARTICLES IN COLLOIDAL SUSPENSIONS, WITH SPECIAL REFERENCE TO PERRIN'S INVESTIGATIONS.—A. W. Porter and J. J. Hedges (*Trans. Faraday Soc.*, **18**, 91, 1922).

VIII.—HISTORICAL, EDUCATIONAL INSTITUTIONS, ETC.

FAENZA AND URBINO MAJOLICAS AT FLORENCE.—G. Ballardini (*Faenza*, **10**, 144, 1922). A brief note, taken from documents supplied by Prof. Supino of Bologna university.

THE NAIROBI BRICK, TILE AND PIPE WORKS, LTD.—(*Brit. Claywr.*, **32**, 61, 1923). A short, descriptive article.

CERAMIC PRODUCTS THROUGH THE CENTURIES.—F. Fremersdorf (*Südd. Tonind.*, **5**, 261, 1923).

APPLICATIONS OF PHYSICS TO THE CERAMIC INDUSTRIES.—J. W. Mellor (*Nature*, **111**, 757, 1923). A condensed report of a lecture forming the fourth of a series on "Physics in Industry." Specific applications of sound, light, heat, electricity and magnetism, and mechanical science in the manufacture of pottery and glassware are dealt with.

THE MAJOLICAS OF FERRUCCIO MENGARONI.—L. Serra (*Corr. Cer.*, **4**, 83, 1923). A historical sketch. The article includes 20 illustrations.

CERAMIC ART AND ARCHITECTURE.—G. Ferrand (*J. Amer. Cer. Soc.*, **5**, 743, 1922). A discussion of the architectural uses of terra cotta both externally and internally.

GREEK VASE FROM THE BOLOGNA MUSEUM.—P. Ducati (*Faenza*, **10**, 52, 1922).

THE MOSAICS OF THE ALAMBRA.—L. S. de Lucena (*Faenza*, **10**, 54, 1922).

"OBRA DE MALICA" AND THE CERAMICS OF GRANADA; VASES OF THE ALHAMBRA.—G. Ballardini (*Faenza*, **10**, 57, 1922).

A RARE LOVING CUP BEARING THE MANFREDI AND BENTIVOGLIO INSIGNIA.—G. Ballardini (*Faenza*, **10**, 89, 1922). An interesting historical introduction is followed by an illustrated description of the cup, or bowl, now in the Ceramic Museum of Faenza.

ITALIAN PHARMACY OF THE XV. CENTURY IN THE HISTORY OF CERAMIC ART.—A. Castiglioni (*Faenza*, **10**, 76, 1922).

ORNAMENTAL CERAMICS AT VITERBO.—G. Rosi and U. Richiello (*Faenza*, **10**, 122, 1922).

Abstracts.

1.—RAW MATERIALS.

GENERAL.

ON CLAY.—Toshi Suzuki (*J. Jap. Cer. Assoc.*, **370**, 310, 1923). Clays are classified into two groups, *i.e.*, residual clay and transported clay. Residual clay has chiefly been produced by weathering of felspathic rocks, although it has often been produced by the action of hot springs or sulphurous vapours. (i.) Residual clays due to the action of weathering. Clays of Hanasaka and Gokokuji (used in Kutani-ware) as well as that of Izushi (used in Izushi-ware) are kaolins from liparite. Gairome-clays produced in the provinces of Mikawa, Owari, Mino and Iga are kaolins from granite. The very plastic reddish brown clay used in Onko-ware is a residue of a calcareous rock, whose calcium carbonate has been dissolved away by weathering. (ii.) Residual clays due to the action of hot springs or sulphurous vapours. Some of the clays used in the manufacture of Satsuma-ware were produced from augite-andesite by the action of sulphurous vapours and hot springs. Izumi-yama clay used in Arita-ware is a residue of liparite which was decomposed by the action of sulphurous gases. Tobe clay used in Tobe-ware was produced by the combined action of hot springs and weathering on mica-andesite. Clays used in the manufacture of Aizu-ware, as well as amalgatolite of Mitsuishi, were produced by the action of hot springs on liparite. (iii.) Transported clays. Fukushu clay is a fireclay of the coal measures. Kibushi-clays found in Mino, Owari, Ise and Iga, those used in Banko and Tokoname stonewares, clay used in Shigaraki-ware, the raw material of Awaji fayence and many clays used in the manufacture of crude fayence, as well as architectural pottery, are of Tertiary origin. Diluvial and alluvial clays are used in the manufacture of Takatori and Imbe stonewares and of most of the crude fayence, roofing tiles, sewer pipes, common bricks, etc. S. KONDO.

STUDIES ON THE DOLOMITE SYSTEM—PART II.—A. E. Mitchell (*J. Chem. Soc.*, **123**, 1887, 1923). The process of formation of dolomite was studied, and an attempt made to prepare it in the laboratory. An apparatus for the determination of the solubility of substances under moderately high pressures of carbon dioxide was designed, and proved satisfactory. It was shown that dolomite could be prepared from an aqueous solution of calcite and nesquehonite in the presence of carbon dioxide up to 20 atm. pressure. The physical properties of the prepared substance were comparable in every way with the purest natural mineral.

THE ACTION OF SILICA ON ELECTROLYTES.—A. F. Joseph and J. S. Hancock (*J. Chem. Soc.*, **123**, 2022, 1923). The object of the paper is to suggest that the changes observed when silica is added to a solution of a simple electrolyte, such as sodium chloride (solution rendered acid) can be sufficiently accounted for on the lines of straightforward chemical reactions. The authors state that the effect of silica upon a salt solution appears to be due to a chemical change resulting in the formation of free acid and of a complex silicate of low solubility but alkaline reaction. Pure silica produces no effect on a solution of an acid.

RAW MATERIALS: OCCURRENCE, PREPARATION, ETC.

DIATOMACEOUS EARTH PRODUCED IN THE ISLANDS OF OKI.—Denzo Sato (*J. Jap. Cer. Assoc.*, **369**, 264, 1923). The geology of the island is given in details. There are three large deposits of diatom. earth in the islands. Analyses of typical products are :

Deposit	Insol. matter	Sol. SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	K_2O	Na_2O	Loss	Total
Iinoyama	43·93	37·51	1·17	3·06	0·00	0·10	0·57	0·28	13·06	99·77
Kamo ..	34·37	48·05	1·38	2·80	trace	0·36	0·32	0·15	12·54	99·97
Minoura	34·25	46·32	0·75	3·60	0·00	0·27	0·63	0·23	13·54	99·59

S. KONDO.

PATENTS.

DRYING CHINA CLAY.—N. Testrup and Techno-Chem. Laboratories (*Pat. J.*, 1,771, 1922). No. 188,010, May 30th, 1921. China clay of large water content is precipitated in a settling tank or centrifugal separator, and the cleanest clay from the precipitated layer is discharged to a dryer, consisting of a surface heated by compressed evoled vapour, the dried clay being refined by separation in a moving gaseous medium.

PURIFYING CLAY.—W. Feldenheimer and W. W. Plowman (*Pat. J.*, 1808, 1923). No. 199,795, Mar. 27, 1922. The clay is peptised in an aqueous solution of caustic alkali, such as caustic soda, which contains the hydrate of an alkaline earth (calcium, barium, strontium), The solution of mixed hydrates may be obtained by the interaction of an excess of caustic alkali and an alkaline-earth hypochlorite such as bleaching powder in the presence of water. The suspension of clay may be separated from the unpeptised impurities and the clay recovered in any desired manner. A soluble hypochlorite may also be present for bleaching, deodorising and sterilising the clay, or it may be added to the suspension after the impurities have been removed.

PHYSICAL AND CHEMICAL PROPERTIES, TESTING, ETC.

ON THE DEHYDRATION OF KAOLIN AND ITS BEHAVIOUR IN THE SOLID STATE TOWARD THE CARBONATES AND OXIDES OF THE ALKALINE EARTHS.—G. Tammann and W. Pape (*Zeits. anorg. Chem.*, **127**, 43, 1923). The work of previous investigators is briefly reviewed. The authors state that further tests were necessary, in order to decide between the different theories put forward by previous workers, *e.g.*, Mellor and Holdcroft, Sokoloff, Keppeler, Le Châtelier, Samoilov, and Knote. The experiments were conducted on Oschatz Earth, which had been dried for 2 hours at 150°. For the rehydration tests, the clay was heated for 1 hour to 600°. Similar tests were also carried out with pure alumina and pure silica. The main result of the work is summarised as follows : After dehydration at 550°, kaolin decomposes into Al_2O_3, SiO_2 and water. At 930° the Al_2O_3 liberated at 550° is changed into another form. The reasons which support this decomposition theory are : (1) After dehydration at 550° the Al_2O_3 in kaolin becomes soluble in acids. (2) On heating to 800-900° pure Al_2O_3 is not readily soluble in acids, and the same applies to the Al_2O_3 in kaolin. (3) Between 850 and 1060° pure kaolin develops a considerable amount of heat ; and at 930° kaolin develops an amount of heat which corresponds approximately with its Al_2O_3 content. (4) During the process, the Al_2O_3 becomes denser, and kaolin also exhibits a marked increase in density. (5) At a pressure of 1 atm. the dissociation temperature of the alkaline earth carbonates is diminished by 220° by Al_2O_3. Kaolin effects the same result. (6) On heating a mixture of Al_2O_3 and SiO_2, evolution of heat takes place at 940°, as with kaolin, the Al_2O_3 becoming less readily soluble in both cases. This tendency to become less soluble also occurs when Al_2O_3 is heated alone.

UTILIZATION OF A WASTE ALUMINA.—Iwazo Takita and Masajiro Wataya (*J. Jap. Cer. Assoc.*, **366**, 98, 1923). The research relates to the utilization of impure alumina which is obtained as a waste product in the

process of extracting alum from calcined alunite. The waste alumina of the Asada Alum Works, Shikama, Harima, was used in the experiments. (1). Properties of the waste alumina. Analysis of the waste alumina gave SiO_2 28·50, Al_2O_3 65·33, Fe_2O_3 0·56, CaO 1·25, K_2O 1·80 and SO_3 2·46%. The refractoriness exceeds cone 37. (2). Manufacture of chemical porcelain. Experiments on the manufacture of chemical porcelain with seven different bodies and seven glazes are described. The best result for cone 16 was obtained with No. 1 body and a glaze. No. 1 body was composed of 23·2 waste alumina, 33·7 Gairome-clay of Tokiguchi, 25·0 Ohmishima quartz and 18·1% Ohmishima felspar. Its formula is $0{\cdot}1036K_2O,Al_2O_3,3{\cdot}1303SiO_2$. Small crucibles were formed by casting a slip composed of 100 raw materials, 0·25 sodium carbonate, 0·08 water glass and 90 water. The glaze which was applied to the biscuits corresponded to: $\left\{\begin{matrix}0{\cdot}1K_2O\\0{\cdot}9MgO\end{matrix}\right\}$ $1{\cdot}0Al_2O_3$, $10{\cdot}0SiO_2$, in which MgO was added in the form of calcined magnesite. The glazed biscuits were fired to cone 16. The products stood various tests better than German crucibles. (3). Manufacture of glass pots. Small pots made of 18 different bodies by casting, and fired at cones 010a, 8 and 15, were filled with a glass mixture composed of 38·22 cryst. borax, 12·40 boric acid, 92·04 barium oxide and 36·00 sand ; they were heated to cone 8 to compare their resistance to corrosion. Detailed descriptions are given on the procedure and results of the experiments. (4). Manufacture of refractory brick. Superior bricks were obtained by the following process : the waste alumina is ground, pressed into briquettes, fired at cone 18 and reground ; bricks made of 80% grog and 20% raw Kibushi-clay are fired at cone 16. Their shrinkage was 0·44% in drying and 0·33% in firing. Their refractoriness exceeded cone 37. S. KONDO.

II.—MANUFACTURING PROCESSES:

GENERAL.

POROUS SLAG BRICKS.—A. Frisak (*Stahl Eis.*, **43**, 1,219, 1923). A new process is described for the manufacture of light bricks from blast-furnace or other slags. The methods of producing porous slags, their properties before solidification, strength, thermal conductivity, composition and pressure of the pore gases, permeability to air and water, resistance to weather, and the sulphur content of the pure gases, are discussed. The figures for crushing strength, specific gravity and thermal conductivity (k) are tabulated. Slags can only be rendered porous by treatment with water, and not with air or dry steam. The porosity can be controlled within wide limits. Slags have been prepared with a porosity of 97%, corresponding to a sp. gr. of 0·075. The scum-forming SiO_2–Al_2O_3–CaO–slags occupy a large area on the triangular diagram of these compounds. Natural slags coming within this area are all suitable, provided their content of oxides such as Fe_2O_3, FeO, ZnO, MnO and CuO is not too great. The limit for FeO is about 3%. The swelling property of a slag is not affected by other ingredients, *e.g.*, MgO, alkalies and sulphur. For a given temperature the viscosity of porous slags is higher than that of the dense varieties. The thermal conductivity of the porous slag bricks was found to vary almost directly with the sp. gr. ; the finer the air pores, the lower the thermal conductivity. A special apparatus for the determination of the thermal conductivity of the bricks is illustrated. With proper cooling, cast bricks of the type described, as made by the Norwegian process, have a much higher crushing and impact strength than the ordinary slag bricks.

EXPERIMENTS ON THE MANUFACTURE OF PURE-WHITE HARD PORCELAIN.—Mikiya Akatsuka (*Report of the Pottery Laboratory, Kioto*, **1**, 1-13, 1922). Many experiments were carried out with the object of producing pure white porcelain with Korean kaolin as its chief raw material.

The firing temperature was Cone 14 all through the series. (1). *Raw materials.* Korean kaolin of Daiyamen, Katogun, Keishonando, Gairome clay (highly plastic kaolin) of Tokiguchi, felspar and quartz from the Ehime prefecture, and talc from South Manchuria were used. The Korean kaolin gave the following analysis: 45·06 silica, 38·44 alumina, 0·54 ferric oxide, 0·73 lime, 0·16 magnesia, 0·80 alkalies and 14·32 loss on ignition. (2). *Composition of body.* Its range was clay 54-67% (kaolin 33-53%, Gairome clay 6-21%), felspar 21-29% and quartz 12-18%. These materials were used in the air dry state. The moisture content was as follows: kaolin 6·64%, Gairome clay 6·32%, felspar 0·20%, quartz 0·08% and talc 0·08%. (3). *Glaze formula.* The glazes tried were:—

(1) 0·65 K_2O, 0·35 MgO } 0·75-0·90 Al_2O_3 : 9·5-10·0 SiO_2;

(2) 0·7 K_2O, 0·3 MgO } 0·8-1·2 Al_2O_3 : 9·0- 12·0 SiO_2;

(3) 0·75 K_2O, 0·25 MgO } 1·0 Al_2O_3 : 9·0 SiO_2 and

(4) 0·80 K_2O, 0·20 MgO } 0·85-0·95 Al_2O_3 : 8·5 SiO_2.

They were composed of felspar, Gairome clay, talc and quartz. (4). *Bending and shrinkage of bodies.* Descriptions are given of the experiments. (5). *Forming.* The workability of the body was tested by the usual methods, including casting, 0·3% sodium carbonate being added to the casting slips. (6). *Glazing.* Glaze slips, rich in felspar, are liable to settling. Consequently a small amount of acetic acid (about 20-30 c.c. to a 72-litre cask) was added. Its effect is not temporary as is that of ammonium carbonate. (7). *Results.* (*a*). The most suitable grinding time for bodies was 25 hours with a 100-kg. wet grinding cylinder. It was 35 hours for the glaze when the same grinding cylinder was used. Talc has to be ground for 20 hours before it is used in glaze batches. (*b*). The following bodies were excellent as regards forming, cracking in drying and burning colour:

Korean Kaolin	Tokiguchi Gairome	Ehime felspar	Ehime quartz
33	21	28	18
38	17	28	17
44	19	23	14

(*c*). Glazes of the formulae, 0·65 K_2O, 0·35 MgO } 0·90 Al_2O_3 : 10·0 SiO_2;

0·70 K_2O, 0·30 MgO } 0·90 Al_2O_3 : 10·0 SiO_2;

0·70 K_2O, 0·30 MgO } 1·20 Al_2O_3 : 11·0 SiO_2 and

0·70 K_2O, 0·30 MgO } 1·20 Al_2O_3: 12·0 SiO_2 were satisfactory. The last glaze, which was an excellent one, was further improved in colour and lustre by partly replacing the Gairome clay with kaolin. The batch was as follows: Ehime felspar 41·4, Tokiguchi Gairome 8·0, Korean kaolin 5·7, Manchurian talc 4·0, and Ehime quartz 40·8. (*d*). Most of the 27·4 cm. plates shrank to 24·6 cm. S. KONDO.

ROOFING TILE INDUSTRY IN THE ISHIKAWA PREFECTURE.—Kyotaro Koyama, Tomozo Ishida and Yoshitaka Nakamura (*J. Jap. Cer. Assoc.*, **369**, 243, 1923). Only glazed roofing tiles are produced in the Prefecture. The body is composed of one or two kinds of local clays with or

without addition of a sandy clay or a sand. Eight kinds of clays, each used as the sole body material, have the composition: Silica 59·49-67·77, alumina 13·46-20·21, ferric oxide 3·53-7·52, lime 0·51-4·41, magnesia 0·06-2·21, alkalies 0·03-0·82 and loss on ignition 7·60-16·16%. The body is prepared by kneading the material with or without the aid of a pug mill and clay cutter. No machine is used in the forming. The tiles are glazed after biscuit-firing. Glazes are composed of local rock, ferric oxide and pyrolusite, sometimes with the addition of galena. They are fired in semi-continuous kilns called "Noborigama" to cone 6a-9. All samples taken from 17 manufacturers successfully withstood the usual test for freezing. The absorption in 48 hours ranged from 3·4 to 17·7%. S. KONDO.

PATENTS.

BUILDING MATERIAL.—H. H. Robertson Co. (*Pat. J.*, 1,784, 1923). No. 192377/8, Jan. 15, 1923. Roofing and other building material consists of a fibrous foundation covered with asphalt or similar bituminous material, to the outside of which a coating of molten metal (lead, zinc or copper) is applied, and a second metallic layer is similarly applied by electro-deposition or by immersion in a suitable solution.

DOLOMITE BRICKS.—T., J., W. and T.A. Hodson (*Pat. J.*, 1,787, 1923). No. 193576, Dec. 17, 1921. Refractory basic bricks, furnace linings, retorts, etc., are obtained by calcining dolomite, magnesite, or magnesian limestone, adding small quantities (15%) of igneous rocks other than granites and syenites, and in some cases a little basic iron ore, mixing with water, moulding, and firing at 2,000°C.

REFRACTORIES.—C. S. Garnett, W. A. Reid, F. E. S. Greenwood, and F. S. Cowlishaw (*Pat. J.*, 1,799, 1923). No. 197791, Mar. 18, 1922. Dolomite or magnesian limestone is partly calcined so as to contain 8-12% CO_2. To the calcined product, mineral substances, such as silicates or oxides, which prevent hydration, are added, and the mixture is made plastic with water, moulded into bricks, either before or after slaking is completed, and fired at about 1,500°.

COMPOUNDING AND PREPARATION OF BODIES, ETC.

FIRE-BRICKS.—W. Meese (*Pat. J.*, 1,801, 1923). No. 198,463, 13 Mar., 1922. A fire-brick mixture consists of two parts white or brown sandstone and one part red clay.

TRANSPARENT POTTERY BODY.—J. E. Tams (*Pat. J.*, 1,802, 1923). No. 198,607, 16 Sept., 1922. A transparent body similar to china, felspar or parian, contains powdered asbestos and powdered frit produced from powdered asbestos and soda fritted in the usual way and ground. China clay, felspar, or stone may be added.

POTTERY BODY.—W. Green (*Pat. J.*, 1,802, 1923). No. 198,817, Mar. 18, 1922. Hand porcelain ingredients containing potash, etc., are incorporated with a sintered, irreducible oxide (*e.g.*, pure alumina or zirconia) and fired to a high temp. The composition may consist of alumina, potash felspar, china-clay, and ground flint.

REFRACTORY ABRASIVE COMPOSITION.—L. E. Bourdeau (*Pat. J.*, 1,808, 1923). No. 200,903, Apr. 19, 1922. The composition is prepared by fusing a mixture of bauxite and basalt mainly, with smaller proportions of ilmenite, cerite, carbon, and a flux such as sodium fluosilicate.

SHAPING, MOULDING, DRYING, ETC.

ELECTRIC INSULATORS.—A. E. Wilson and Callender's Cable and Construction Co. (*Pat. J.*, 1,798, 1923). No. 197,490, Mar. 31, 1922. In the insulator described, the petticoat is formed integral with the central boss, which is moulded round a metal cone and within a conical metallic ring.

CASTING TEA-POTS.—W. W. A. Croxten (*Pat. J.*, 1,804, 1923). No. 199,524, Apl. 7, 1922. Tea-pots are cast with integral spout, body and handle in a two-part mould, having meeting projections adapted to form perforations (*a*) transversely of the spout adjacent the body, and (*b*) between the body and spout.

DETACHABLE TEA-POT SPOUTS.—G. W. Greyke (*Pat. J.*, 1,805, 1923). No. 199,946, July 1, 1922. Related to a detachable spout, which is secured in place in an opening in an inclined facet of a tea- or coffee-pot by being formed with a threaded stem, upon which a locking ring can be secured after the spout has been passed into place from the inside of the vessel. The spout may be formed of Britannia metal.

FACE BRICKS.—F. W. Rurade (*Pat. J.*, 1,807, 1923). No. 200,444, Jan 11, 1923. Facing bricks are made equal in size to three, five or more ordinary bricks, the faces being grooved to represent the joints.

KILNS, OVENS, MUFFLES; FIRING TECHNIQUE, ETC.

ON REFRACTORY CEMENT.—Tei Takamatsu and Masatake Kuwayama (*J. Jap. Cer. Assoc.*, **368**, 167, 1923). The authors worked for the production of substitutes for "Hytempite," which is imported from America. Hytempite has an alkaline reaction, its strength corresponding to 0·0276 g. NaOH per g. of sample. The analysis of a dried sample is: Total silica 68·66, soluble silica 4·33, alumina 16·26, ferric oxide 2·60, lime 1·25, magnesia 0·92, soda 3·73 and loss on ignition 6·53%. It melts at about Cone 15, while its insoluble portion has a refractoriness of cone 27. The effect on refractoriness of adding different amounts of water glass to the insoluble portion of hytempite, seven kinds of domestic clays and a diatomaceous earth are shown. The results indicate a close similarity between Mizuno clay and the insoluble portion of hytempite. The experiments of manufacturing refractory cement with Mizuno clay, grog and water glass are then reported. Analyses of these materials are:

	Silica	Alumina	Ferric oxide	Lime	Magnesia	Soda	Loss on ig.
Mizuno clay	69·12	16·68	0·55	1·80	0·99	—	8·20
Grog ..	73·20	21·84	0·90	1·24	0·83	—	—
Water glass..	36·56		—	—	—	18·81	44·63

Two small slabs cut from firebricks were cemented with each mixture. The blocks were then heated at 1,350°C. (for 8 hours), 1,580° (100 hrs.), 1,510° (104 hrs.), 1,470° (110 hrs.), 1,490° (113 hrs.) and 1,345° (10 hrs.). They were then tested as cements for cracked glass pots. The following mixtures, together with several others, are at least as good as Hytempite:

No.	Mizuno clay	Water glass	Grog	Water
20	30	15	55	9
42	30	25	45	5
43	25	25	50	5

S KONDO.

GAS GENERATORS.—F. Umbleby and H. Powers (*Pat. J.*, 1,797, 1923). No. 196,972, Jan. 4, 1922. Solid or semi-liquid fuels are gasified by continuous passage through a receptacle heated by surface combustion taking place on its outer surface, or on its outer and inner surfaces.

RADIATION PYROMETER.—K. Hase (*Pat. J.*, 1,797, 1923). No. 197,226, June 24, 1922. The optical elements for focussing, etc., a thermo-couple and a galvanometer are all arranged within a single casing. The instrument is described and illustrated.

FURNACE LININGS.—E. Cone and J. W. Hale (*Pat. J.*, 1,804, 1923). No. 199,444, 17 Mar., 1922. A plastic material suitable for neutral linings contains 50 parts graphite, 25 parts fireclay, 5 parts silica rock in 3 to 4-inch lumps, 5 parts magnesite, and sufficient anhydrous gas tar to ensure plasticity. This mixture is compressed in superposed or alternate layers with refractory brickwork.

CHARGING AND DISCHARGING OPEN KILNS.—A. Dubar (*Pat. J.*, 1,807, 1923). No. 200,477, Feb. 10, 1923. Relates to open kilns for burning bricks. The kiln is built up from a vertically adjustable platform, on to which the raw bricks and fuel are raised.

Patents.

SAGGARS.—Itsuro Kasugai. (*Jap. Pat.* 42,575, May 12, 1922). Holes are bored in the sides and bottom of a saggar for the purpose of saving fuel in the glost-firing of porcelain. S. Kondo.

IMPROVEMENT IN KILNS FOR BURNING BRICKS AND SIMILAR WARES.—Tokusaburo Sato (*Jap. Pat.* 42,666, May 20, 1922). The kiln is provided with fire-boxes, each of which has a drop-arch and a channel-shaped wall at its rear. The drop-arch directs the flame produced on the grate downward. The flame then strikes the inverted channel wall, which is a kind of very low flash wall, situated much nearer to the grate than usual. The construction keeps the furnace-end hot and aids the complete combustion of gases. S. Kondo.

BRICK KILN.—Yasaburo Saito (*Jap. Pat.* 42,989, June 30, 1922). This is a parallel ring kiln with two main flues between two firing channels instead of one as usual. Each main flue is connected with the opposite burning channel by small flues which pass under the other. It has a drying chamber on the main flues. Another drying tunnel is constructed around the kiln. Pipes are embedded in the kiln body over the crown. Hot air produced in them by conduction is utilized in drying bricks, by connecting the pipes with the drying chamber and tunnel. S. Kondo.

GLAZES, ENAMELS.

THE WITCHERY OF GLAZES.—P. E. Cox (*J. Amer. Cer. Soc.*, **5**, 939, 1922). The paper deals with the extent of research possible in glazes and the fascination of the work in this field.

COLOURED GLAZES.—(*Chem. Tr. J.*, **72**, 570, 1923). The utilization of the less common metals is discussed. *Uranium Compounds*—The yellow sodium uranate gives a deep orange with lead glazes, and a lemon yellow with low-lead or leadless glazes. In general, the greater the amount of lead in the glaze, the richer the orange colour produced. Using certain proportions of sodium uranate with a lead glaze containing zinc oxide, a rich vermilion red is obtained. In porcelain glazes (cone 10), pleasing slate colours may be produced in glazes containing oxides of cobalt and uranium; at lower temperatures, green glazes are obtained. Brilliant, jet blacks are produced on porcelain with glazes containing 10-15% black uranium oxide when fired under reducing conditions. Both u.g. and o.g. colours are obtainable with soluble uranium salts. Uranium nitrate, with a suitable base, gives good u.g. yellow under oxidisng and neutral

conditions, and good greys or blacks in a reducing fire. *Titanium Compounds.*—The most promising field for titanium oxide is in the development of crystalline glazes. Beautiful effects have been obtained in stoneware glazes by the use of rutile, particularly with small additions of the oxides of molybdenum, tungsten, vanadium or uranium. *Cerium and allied metals.* Little information regarding the use of cerium in glazes is available. Brilliant yellows, resistant to oxidising and reducing conditions, are said to be produced with calcined cerium phosphate after fritting with nitre at cone 13. *Tungsten and zirconium.* In this case, information is even more scarce. Good brown colours have been produced by means of phospho-tungstic acid, or with tungstic acid in combination with iron and manganese. In combination with small amounts of a thorium or radium salt, calcium tungstate imparts self-luminous properties to coloured lead glazes.

STUDY OF TRANSLUCENT HARD-FAYENCE GLAZE.—Jisui Uyeda (*Report of the Pottery Laboratory, Kioto*, No. **1**, 14, 1922). (i.). *Purpose of the study.* The ordinary transparent hard-fayence glaze exposes all the defects on the body just as they are. Moreover, it has an excessive lustre like that of inferior glasses. On the other hand, porcelain has a fine appearance, since it consists of a translucent body, a glaze which is not fully transparent and a translucent intermediate layer. The purpose of the study was to produce a hard fayence with an appearance of porcelain, by improving the said properties of the glaze and also by colouring its body and glaze. (ii.). *Single opacifiers.* Cryolite. This has a tendency to produce devitrified spots. Otherwise, the result was favourable. (2). *Fluorspar.* This acted exactly like cryolite. The use of an engobe composed of 49·5% fluorspar, 41·3% felspar and 9·2% Gairome clay under a transparent glaze was promising, though the uniform application of the engobe was not successful. (2). *Stannic oxide* makes the glaze matt or gives an appearance like an enamel. (4). *Antimony oxide* behaves exactly like stannic oxide. (4). *Zirconia* also acts like stannic oxide, but produces a bluish shade instead of yellow with the latter. (5). *Zinc oxide.* The action of zinc oxide as an opacifier is very weak. However, it makes the glaze white and bright. (iii.). *Compound opacifiers.* (1). *Stannic oxide and fluorides.* Satisfactory results were first obtained with glazes containing 3% stannic oxide and 5% fluorspar or cryolite. Starting with thesee results, the effects of variation in the amounts of stannic oxide, fluorine, alumina and silica were studied. Among numerous batches, the following proved to be the best for Cone 01a :

$$\left.\begin{matrix}0{\cdot}32\ PbO\\0{\cdot}10\ K_2O\\0{\cdot}20\ Na_2O\\0{\cdot}38\ CaO\end{matrix}\right\}\ 0{\cdot}30\ Al_2O_3\ \left\{\begin{matrix}3{\cdot}60\ SiO_2\\0{\cdot}40\ B_2O_3\\0{\cdot}15\ F_2\\0{\cdot}063\ SnO_2\end{matrix}\right. \qquad —(a)$$

The batch was composed of 49·40% frit, 10·17% white lead, 11·17% Korean Kaolin 1·74% Gairome clay and 27·52% quartz. The formula of the frit is

$$\left.\begin{matrix}0{\cdot}191\ PbO\\0{\cdot}119\ K_2O\\0{\cdot}238\ Na_2O\\0{\cdot}452\ CaO\end{matrix}\right\}\ 0{\cdot}119\ Al_2O_3\ \left\{\begin{matrix}1{\cdot}380\ SiO_2\\0{\cdot}476\ B_2O_3\\0{\cdot}178\ F_2\\0{\cdot}075\ SnO_2\end{matrix}\right.$$

0·0475 ferric oxide and 0·00380 cobalt oxide were added to 100 frit batch. (2). *Stannic oxide and zinc oxide.* Excellent result was obtained with a glaze

$$\left.\begin{matrix}0{\cdot}32\ PbO\\0{\cdot}10\ K_2O\\0{\cdot}20\ Na_2O\\0{\cdot}38\ CaO\end{matrix}\right\}\ 0{\cdot}30\ Al_2O_3\ \left\{\begin{matrix}3{\cdot}60\ SiO_2\\0{\cdot}40\ B_2O_3,\\0{\cdot}12\ ZnO\\0{\cdot}063\ SnO_2\end{matrix}\right.$$

composed of 50·0% frit, 10·1% white lead, 11·0%, Korean kaolin, 1·7% Gairome clay of Tokiguchi and 27·2% quartz for Cone 01a-02a. The frit formula was

$$\left.\begin{matrix}0{\cdot}190\ PbO\\0{\cdot}119\ K_2O\\0{\cdot}238\ Na_2O\\0{\cdot}453\ CaO\end{matrix}\right\}\ 0{\cdot}119\ Al_2O_3\ \left\{\begin{matrix}1{\cdot}370\ SiO_2\\0{\cdot}476\ B_2O_3\\0{\cdot}143\ ZnO\\0{\cdot}075\ SnO_2\end{matrix}\right.$$

0·0450 ferric oxide and 0·0045 cobalt oxide were added to 100 frit batch. (3). *Zirconia and fluorspar.* By introducing 0·07 ZrO_2 instead of 0·063 SnO_2 in formula (*a*), a good glaze was obtained. However, it was deficient in lustre, although this was later improved by increasing the amount of fluorspar. (4). *Antimony oxide and fluorspar.* Only a few experiments were made with these opacifiers, as antimony oxide is said to be poisonous. (5). *Bone-ash and fluorides.* Experiments with bone-ash and cryolite or fluorspar gave pretty good results, though the glazes were much inferior in translucency, lustre and colour to those with stannic oxide and fluorspar. (v). *Colouring hard fayence.* (1). *Colouring body.* The use of $CoSO_4.7H_2O$ or $Co(NO_3)_2{\cdot}6H_2O$ is described. An example of good bodies is: 60·0% liparite of Amakusa, 18·0% Gairome clay of Tokiguchi, 17·0% amalgatolite of Mitsuishi, 5·0% felspar and 0·058% cryst. cobalt nitrate (0·015% cobalt oxide). The batch was ground wet for several hours in a grinding cylinder. Then 0·0712% cryst. sodium carbonate was added and ground again. (2). *Colouring glaze.* The usual way of adding cobalt oxide to the frit is not satisfactory, as it produces a blue with a purplish grey shade. Various mixtures therefore were tried. Barium chromate gave the greenish blue of porcelain glazes. For glazes containing stannic oxide the use of a mixture of cobalt oxide and ferric oxide, in amounts of 0·0025-0·003% and 0·025-0·03% respectively, in matured glazes, is recommended. S. Kondo.

STUDY OF ACID-RESISTING ENAMELS.—Tokiji Uchida and Kazuo Arimoto (*The Osaka Industrial Laboratory. Bulletin* iv. No. **1**, 68 pp., 1923) The influence of variation in the composition of enamel-frits upon their resistance to sulphuric acid was determined, starting from standard frits which contain basic flux (Na_2O, $1/3Na_3AlF_6$ or PbO), refractory base ($1/3Al_2O_3$,CaO,ZnO,BaO or MgO), acid flux (B_2O_3) and refractory acid (SiO_2, TiO_2 or ZrO_2) in the ratio of 1·0 : 0·6 : 0·5 : 2·4. The solubility was compared by placing 2 g. of frit, ground to a fineness of 900-1,000 mesh per sq. cm., in a weighing bottle containing 10 c.c. of 10% sulphuric acid and leaving them for 48 hours at 20°C. under normal pressure. (i). Effect of basic fluxes on resistance to acid. (1). The effect of these is practically similar, but soda is better than cryolite or lead oxide. (2). An excess of cryolite causes difficulties in melting, as it badly corrodes the pot, while too small proportions make the frit too refractory. The best result is obtained with 0·8 equivalents. (ii.) Effect of refractory base on resistance to acid. (1). The effect is very marked. The best result is obtained with barium oxide, followed by magnesium oxide. Oxides of zinc, aluminium and calcium are detrimental. (2). The series 0-1·0BaO.$1/3Na_3AlF_6$.$0{\cdot}5B_2O_3$.$2{\cdot}4SiO_2$ is least soluble at 0·3BaO. (iii). Effect of acid flux on resistance to acid. The resistance is reduced by an increase in boric acid. $0{\cdot}3B_2O_3$ is most suitable, since a smaller content makes the frits too refractory. (iv.) Effect of refractory acid on resistance to acid. (1). The effect is remarkable. Only silica is satisfactory among the three acids. (2). The resistance increases as the content of silica rises. (v.) Effect of mutual replacement of base and acid on the resistance to acid. (1). Experiments on series 1·0-0BaO or MgO.2-3, SiO_2.$1/3Na_3AlF_6$.$0{\cdot}5B_2O_3$ show that good frits are obtainable only with certain definite ratios of base and the acid, 0·6BaO or MgO : $2{\cdot}4SiO_2$ being best for the series. (2). Solubility of series 0·6-1·5 $1/3Na_3AlF_6$.0·9-0B_2O_3.0·6BaO.$2{\cdot}4SiO_2$ decreases with the content of cryolite. Considering the difficulties caused by its corrosive action on the pot, the proportion 1·0 $1/3Na_3AlF_6$: $0{\cdot}5B_2O_3$ seems to be most suitable. (vi.) Production of the best frit. Since the experiments hitherto described indicated that Na_2O,B_2O_3,BaO and SiO_2 were most desirable constituents of acid-proof enamels, the authors then started to find their best proportion, keeping

the ratio of fluxes and refractory oxides at 1·3 : 3.7 in equivalents and also the contents of soda and boric acid as 1·1 and 0·2 respectively. The best frit thus obtained is $0{\cdot}3BaO.3{\cdot}4SiO_2.1{\cdot}1Na_2O.0{\cdot}2B_2O_3$. The frit loses only 0·28% in the test, and is quite satisfactory in other respects, such as melting point, burning lustre, burning colour and adherence to iron.

URANIUM GLAZES.—Mikiya Akatsuka (*Report of The Pottery Laboratory, Kioto*, **1**, 57, 1922). (1). *Vermilion glaze.* A raw glaze (*b*) composed of 35 white lead, 10 quartz and 8 ammonium uranate, $(NH_4)_2U_2O_7$, produced a brilliant vermilion at Cone 012a-011a. The addition of Funori glue is recommended. It was applied three times as thick as ordinary porcelain glazes on vitrified porcelain biscuit. (2). *Red glaze.* Replacing 1 part of the uranate with 1 part of ferric oxide in the glaze (*b*), a brownish red was obtained. (3). *Crystal and lustre.* The appearance of the glaze (*b*) changes with firing temperature, thus :

Cone ..	012a	01a	1a	1a–2a	5a	8–9
Fuel ..	wood	coal	wood	coal	coal	coal
Colour of glaze ..	vermilion	reddish orange	blackish brown	reddish brown, blackish brown or reddish orange	yellowish green, vermilion or blackish red	blackish brown
Colour of crystal	—	—	gold	crimson or green	green	—
Colour of lustre ..	—	—	—	—	greenish purple	gold or purple

(4). *Crystal glazes.* The following table shows glaze batches and temperatures at which crystal glazes were developed.

Glazes	P	Q1	Q2	R	S
White lead	70	75	75	70	70
Ammonium uranate	16	15	15	15	16
Quartz	20	19	16	18	20
Rutile	7	7	8	3	—
Cobalt Carbonate ..	—	0·5	1	—	0·5
Zinc oxide	—	—	—	5	—
Cone	5a, 6a	5a	5a, 6a	5a, 8	1a

When a flower vase was glazed with R, set in a saggar which was coated with a glaze composed of 37 white lead, 8 quartz and 11 am.uranate, and burned to Cone 5a, very fine golden crystals were developed on a bright glaze of the same colour. S. Kondo.

STUDY OF CAST IRON ENAMELS.—Yutaka Fukudo (The Osaka Industrial Laboratory. *Bulletin* iv. No. 2, 43 pp., 1923). The process of enamelling cast iron ware in a single coat is described. (i.) Raw materials used in the experiments. Cast iron pieces containing 2·51% carbon, 1·99% silicon, 0·10% sulphur, 0·06% phosphorous and 0·34% manganese were employed. Enamel materials were quartz, red lead, cryolite, soda-ash and sodium nitrate. (ii.) Effect of cast iron. Four kinds of cast iron ranging in the content of carbon from 2·58 to 3·13%, gave almost identical results for given glazes. (iii.) Effect of fusibility of enamel. 510°C. is the most suitable melting point for the purpose. (iv.) Effect of coef. of expansion.

Experiments with 35 different batches show that enamels with expansion-coefficients of 0.0000220-0.0000280 are most suitable. (v.) Effect of opacifier. Cryolite makes an enamel fragile when it is used in excess of 15%. If stannic acid is used, it should be introduced to an enamel when its frit is ground. (vi.) Effect of glazing process and time of firing. Employing an enamel such as $\left.\begin{matrix}0{\cdot}112\ Na_2O \\ 0{\cdot}337\ PbO \\ 0{\cdot}551\ (Na_3AlF_6)\frac{1}{3}\end{matrix}\right\}$ $\left.\begin{matrix}1{\cdot}526\ SiO_2, \\ 1{\cdot}242\ B_2O_3\end{matrix}\right\}$ composed of 25 quartz, 20 red lead, 40 boric acid, 10 cryolite and 5 sodium nitrate, the author got the best results when the enamel was fired at 750°-770°C. for 30-10 seconds after applying the dry powder to hot test pieces, previously heated to above temperatures for 2-4 minutes, or when the enamel was fired at 800°-820°C. for 40-10 seconds after applying the powder to hot test pieces which had just been heated to the same temperatures for 1-3 minutes. (vii.) Surface-treatment of cast iron body. Surface-decarbonization of cast iron prevents the bubbling of enamel. Very excellent result was obtained with test pieces which had been coated with ferric oxide, manganese dioxide or sodium nitrate, placed in a muffle, heated to 850°C. and then cooled very slowly. (viii.) Coloured enamel. The batch described in (vi.) gave excellent coloured enamels when suitable amounts of colorants had been used. For examples, 3 copper oxide, 3 chromium oxide, 3 manganese dioxide and 0·5 cobalt oxide produce a light sky blue, a dark green, a dark brown and an indigo blue respectively. S. Kondo.

Patents.

ENAMELLING ALUMINIUM.—K. Warga (*Pat. J.*, 1,781, 1923). No. 191,771, Aug. 16, 1921. Multicoloured decorations, designs, etc., are printed lon aluminium, or aluminium alloy surfaces and enamelled. Films comprising mixtures of mineral colours or pigments and vitreous flux with a liquid or viscous vehicle are printed successively on the metal surface. The mixture adjacent the metal has the lowest melting-point, and the melting points of the successive films rise progressively. The metal surface is oxidised prior to printing, and the films are fixed by firing in a kiln, in which a temperature corresponding to the highest m.p. is maintained.

FIRING ENAMELS.—Chemische Werke vorm. Auer Ges. (*Pat. J.*, 1,800, 1923). No. 197,933, May 10, 1923. To prevent opaque enamels from bubbling during firing, a portion of the clay added to the mill is first made incandescent and then added to the other ingredients. One-half of the clay may be so treated. The process is particularly applicable when zirconium or cerium oxide is present.

III.—FINISHED PRODUCTS, TESTING, ETC.

COMPARATIVE EXAMINATION OF THE STRUCTURE OF JAPANESE AND FOREIGN PORCELAINS. R. Shigemune. (*Tokio Industrial Lab. Report* **17**, No. 6, 1922). The microstructure of 33 Japanese and 24 foreign porcelains, mostly table wares, has been examined. (1). *Porosity of the body*. The maximum and minimum sizes of pores in each section are given. There are two kinds of pores. One, which seems to have been produced in forming, is large and has indefinite shape. It is frequently long and thin along the surface of the body. Sometimes it is developed at right angles to the surface with round sections. The other kind of pore, which seems to have been produced by the evolution of water-vapour and gases, is round and usually small. (2). *Size of grains*. The maximum and minimum sizes of quartz grains in each section are shown in a table. (3). *Appearance of Ingredients*. The degree of fusion of the quartz grains is described for each thin section. (4). *Formation of sillimanite and translucency of body*. The translucency of the body depends on the degree of mutual melting of the raw materials, the amount of ferric oxide, the density in black spots produced by the massing of iron due to the

melting of biotite and other ferruginous minerals, and the formation of sillimanite. The sillimanite, black spot and biotite formations are described for each thin section. The thin sections may be classified by the degree of sillimanite formation into (*a*) sections showing no sillimanite, (*b*) those in which some of the felspar grains are replaced by masses of minute fibrous crystals, (*c*) sections whose felspar has been sillimanitized almost entirely, and (*d*) sections whose groundmass contains minute fibrous crystals. Black spots are usually round, measure mostly 0·001-0·2 mm., and are the only opaque body in the thin sections. The result of burning a cone-9 body composed of Katogun Kaolin 35%, Hakunoto quartz 23%, Omishima felspar 35% and Tokiguchi kaolin 7%, to Cones 9, 12 and 15 indicates that black spots grow in size but diminish in number, as the burning temperature rises. (5). *Japanese porcelains.* Japanese porcelains may be classified into two groups: (*a*) Porcelain made of plastic clay, felspar and weathered granite. Thin sections are usually light brown and have sillimanite in their groundmass. (*b*). Porcelain mainly made of decomposed acid rock. Porcelain which has been mainly made of weathered liparite has no sillimanite in the groundmass, though its felspar grains are rarely sillimanitized. It is generally fine-grained and is light grey or white. The microstructure of Kutani wares, which are made of Hanasaka rock (weathered quartz-porphyry) 5-6, Gokokuji rock (weathered quartz-porphyry) 4-5 and Nabetani clay 3-6, resembles that of porcelain (*a*). (6). *Comparison of Japanese and European Porcelains.* (*a*). *Pores.* Pores in the European porcelains are generally fewer and smaller than those in Japanese wares. (*b*). *Size of quartz grains.* Generally speaking, quartz grains in the European wares are smaller than those in Japanese porcelains. (*c*). *Appearance of quartz grains.* Quartz grains in the European wares have glassy outlines, while only a few Japanese porcelains show similar structure. (*d*). *Formation of Sillimanite.* The European porcelains are generally superior to the Japanese in this respect. (*e*). *Translucency.* Japanese porcelains are generally superior to European in translucency. 39 microphotographs are given. S. KONDO.

ON THE THERMAL PROPERTIES OF REFRACTORIES AT HIGH TEMPERATURES.—Yoshiaki Tadokoro (*Report of the Research Laboratory, Imperial Iron Works*, No. **2**, 1922). Chapter 1. Refractory Materials. Descriptions of their important properties are given. Chapter 2. Classification. Raw materials, proportions and methods of manufacturing various fire bricks at the brick plant of the Imperial Iron Works in Yawata are described. Chapter 3. Properties required in refractory materials and their measurement at high temperatures. Chapter 4. Apparatus for measuring coefficient of expansion and its manipulation. At one end of cylindrical test piece, 30 mm. in dia. and 180 mm. long, four small round holes, 5 mm. in dia. and 30, 80, 130 and 80 mm. deep, were bored symmetrically to its axis and three quartz tubes and a thermo-couple were inserted in them. The other end of the test piece was fixed by a quartz tube. It was heated in an electric furnace with two platinum coils. Its expansion was calculated from the rotation of three mirrors attached to the ends of the quartz tubes. Chapter 5. Results of experiments. 1. Linear change of raw silica brick in heating. (*A*.) First heating and cooling. Experimenting with a dry raw silica brick, composed of 78·4% Tamba quartzite, 19·6% Usuki quartzite and 2·0% CaO, the following result was obtained: (1) The test piece expanded about 1·35%, when it was heated to 575°C.; Then the expansion stopped abruptly, probably owing to the transition of α quartz to β. (2). No change in length was observable up to 870° where a slight contraction, about 0·05%, corresponding to the transition of α tridymite to β_2, took place. (3). No remarkable change occurred between 870°-1,130°; At the latter temperature, sudden expansion occurred due, probably to the acceleration of the transition of β quartz to β cristobalite at 1,250° by the impurities; The expansion between 575° or 1,130° and 1,300°, amounting to 0·85% of original length, was irreversible. (4). Cooling curve shows no linear change between 1,300°-570°. It began to descend suddenly at 570°, leaving 0·98%

expansion at ordinary temperature. In addition the heating and cooling curve shows some changes at 200°-300°C. (A similar result was obtained when the experiment was repeated once more with another test piece of same body). (*B*). Second heating and cooling. The same test piece was heated once more to 1,300° and cooled. The reversible parts of the curve were similar to the former. The irreversible change was slight and no permanent expansion was caused by the treatment. (*C*). Third heating and cooling. The inclination of the curve obtained was similar to that of the experiment *B*. 2. Heating and cooling curves of silica bricks. Burned bricks made of Dairen quartzite showed permissible permanent expansions only in third or fourth heating to 1,300°, while those made of red and white piebald quartzite, as used in experiment 1, indicated no permanent expansion in the first treatment. 3. Irreversible expansion of a red quartzite. A red quartzite, containing 94·26 SiO_2, 2·10 Al_2O_3, 1·40 Fe_2O_3 and 0·84 CaO, was heated at various temperatures to find changes in weight and permanent expansion. The result seems to comply with that of experiment 1. 4. Coefficient of expansion of various bricks. The following table shows the coefficients of five kinds of bricks:

	Magnesia brick.	Silica brick.	Chrome brick.	Grog brick.	Red brick.
Mean coef. of expansion. (20°-1000°C.)	$1{\cdot}255\times10^{-5}$	$1{\cdot}142\times10^{-5}$	$0{\cdot}902\times10^{-5}$	$0{\cdot}760\times10^{-5}$	$0{\cdot}700\times10^{-5}$

Calculated expansions of a by-product coke oven and a blast furnace, assuming their mean temperature as 1,000°, agreed pretty well with facts. 5. Expansion curve of coal. Test piece made of 2 mm. grains of Futase coal and 10% water shrunk about 2·5% at 300°-400°. 6. Expansion of slag brick and slag cement. 11 curves are given. 7. Experiments on Manchurian magnesites. Chemical compositions of the samples were as follows:

Colour	SiO_2	Fe_2O_3	Al_2O_3	$CaCO_3$	$MgCO_3$
Blue	20·02	0·48	0·14	0·90	79·03
White (slightly pinkish) ..	16·62	0·72	0·32	0·60	81·42

A. Dissociation at ordinary pressure. The dissociation began at 400°, was most vigorous at 600° and was nearly completed at 800°. *B*. Irreversible changes in length, sp. gr. and weight. Each test piece was a cylinder, 30 mm. in dia. and 30 mm. long, cut from one of the said ores, and was heated in an electric carbon-resistance furnace for ½, 1 or 2 hours at constant temperatures. White magnesite showed max. expansion of 0·6% at 600°, contracted to original length at 800° and shrunk 4% at 1,400°. Blue sample expanded 0·2% at 600°, shrunk to original length at 800° and contracted 3% at 1,300°. Abrupt contraction occurred at the last temperatures, indicating their incipient fusion at 1,300° or 1,400°C. The loss in weight occurred almost entirely at 400°-800°. Sp. gr. was 3·0 for 100°-600°, 1·6 for 800°-1,400° (800°-1,300° for the blue magnesite) and 2·5 for 1,400°-1,700°C. Slaking test. The results of slaking tests in the atmosphere or boiling water indicated that the Manchurian magnesites must be burned at least to 1,300° or 1,400°. *D*. Expansion and contraction of magnesite at high temperatures. The white magnesite expanded with temperature until 600° was reached where its expansion amounted to 1·4%. Beyond 600°, slight contraction began. It shrunk rapidly at 1,100°C. The cooling curve is almost straight. Chapter 6. Technical position of refractories. A short discussion is given on the subject. S. KONDO.

MICROSCOPIC STRUCTURE OF COMMON BRICK.—Seiji Kondo (*J. Jap. Cer. Assoc.*, **370**, 283, 1923). The structure of common bricks manufactured at the two largest plants in the Tokio and Osaka districts was examined. The chief raw materials are loams in Tokio and stoneware-clays in Osaka, small proportions of sand being used at both plants. The mineral

compositions are given. The bricks are made with spiral presses and burned in ring kilns. They are classified into 8 grades in Tokio and 6 in Osaka. Quality of the bricks is as follows:

	Tokio:		Osaka:	
	Grade 1.	Grade 8.	Grade 1.	Grade 6.
Absorption in 48 hrs. ..	9·94%	18·17%	6·66%	14·60%
Porosity	27·04%	36·87%	22·93%	32·29%
Crushing strength (kg. per sq. cm.) ..	554	139	595	162

(i.) Structure of the Tokio bricks. Thin sections of bricks, which were burned to cone 09a-05a in a ring kiln in Tokio, show plagioclase, quartz, impure dehydrated clay, hypersthene, orthoclase and very small amounts of microcline, hornblende and fragments of groundmass. Hypersthene has slight sign of fusion even in grade 8. Plagioclase in grades 1-5 and orthoclase in grade 1 show similar signs. Grades 1-5 have slight amounts of glass. (ii.) Structure of the Osaka bricks. Thin sections of bricks, which were burned at cone 05a-3a in a ring kiln in Osaka, contain quartz, impure dehydrated clay, orthoclase, radiolaria quartzite, plagioclase and slight amounts of microcline, hypersthene, hornblende and biotite. Plagioclase in all grades, hornblende in grades 1-5 and quartz, orthoclase as well as microcline in grades 1-4 are melted in varying degrees. Even grade 6 contains a small quantity of glass. Grades 1-4 have considerable amounts of sillimanite. (iii.) Mineral composition. Approximate mineral compositions of the bricks have been calculated from their analyses, under the assumption that the bricks have only seven constituents as described below and also that hypersthene has a definite composition corresponding to $3MgO.2FeO.5SiO_2$

Brick	Orthoclase and microcline	Albite	Anorthite	Hypersthene	Dehydrated Clay	Quartz	Ferric oxide
Tokio	10·5	15·0	15·8	13·0	17·0	23·6	5·1
Osaka	13·0	6·6	2·4	3·6	18·7	52·1	3·6

(iv.) Formation of glass. Of the Tokio bricks, grades 1-3 contain small amounts of colourless and light brown glasses, while grades 4 and 5 have only light brown glass. Of the Osaka bricks, grades 1-3 have considerable amounts of light brown glass with many cracks and bubbles and also cracked colourless glass which appears to fill most of the voids in the thin sections, the diameters of these glasses being often as large as 1·1-1·5 mm. Grade 6 has only a small amount of light brown glass. The fact that quartz, felspars and the other minerals were melted at such low temperatures and also that considerable amounts of glass were formed, may probably be due to the presence of minute particles of various minerals and their products of decomposition, which would compose very fusible mixtures not uniformly distributed all through the body. These eutectic mixtures probably melt at first in the firing, and the glass acts on the grains of quartz and other minerals to dissolve them. Large colourless glasses in thin sections of the Osaka bricks have often regular outlines or small nuclei of quartz or felspars. (v.) Formation of sillimanite. Grades 1-4 of the Osaka bricks have considerable amounts of sillimanite; many crystals in grades 1-4 are as long as 0·05-0·02 mm. Twelve microphotographs are given. S. KONDO.

V.—GLASS: GENERAL.

COLOURING GLASSES WITH COBALT COMPOUNDS.—Kitsuzo Fuha (*J. Jap. Cer. Ass.*, 364, 587, 595 (1923). The Colouring action of cobalt compounds on various glasses was studied. Formula of basal glass was $R_2O.RO.3SiO_2$; $R_2O.RO.0{\cdot}5B_2O_3.3SiO_2$; $1{\cdot}3R_2O.RO.6SiO_2$ or $R_2O.B_2O_3.6SiO_2$, in which R_2O is Na_2O or K_2O and RO represents CaO, MgO, ZnO, BaO or PbO. Results: (1) Colour produced by CoO is stable and accordingly is alike for almost all kinds of glass except the pinkish shade in soda glasses which can be distin-

guished from potash glasses only when the amount of the oxide is small; (2) No difference in colouring power was observable between cobalt carbonate and cobalto-cobaltic oxide, Co_3O_4, obtained by igniting cobalt nitrate, if equivalent amounts were used; (3) Addition of small amount of alkali nitrate, potassium tartarate or arsenious acid to the batch had no influence on the colouring.
S. KONDO.

TEMPERATURE IN POT-FURNACES.—Sangora Takahashi (*The Tokio Electric Co., J. Jap. Cer. Ass.*, 364, 609-618 1923). The author performed numerous experiments with two pot-furnaces having 10 or 16 covered pots and gives detailed descriptions or discussions on (1) calorific power of their coal; (2) heat required for melting their glass batch; (3) composition and calorific power of their producer-gas; (4) amount of air required for the complete combustion of the producer-gas; (5) the theoretical combustion temperature; (6) lowering of the temperature due to the heat absorption of the glass-batch and the conduction through furnace-walls; (7) variation in the climate in Tokio; (8) influence of climate on the draft of their stacks; (9) lowering of furnace-temperature due to wet coal; (10) measured temperatures in their furnaces and also (11) on the influence of season upon the cracking of glass pots. Heat utilized in melting batch was 8·6%, in a half-gas fired furnace "*A*" containing 16 300-kg.-pots, and 10·4%, in a Mond-gas fired furnace "*B*" containing 10 250 kg.-pots, of that generated in each furnace by the combustion of the gases. Heat lost by conduction through furnace-walls amounted to 15·9% in "*A*" and 19·0% in "*B*" The mean max. temperature observed close to pots was 1,522°C. in "A" and 1,517° in "*B*."
S. KONDO.

MANGANESE COMPOUNDS AS GLASS COLORANTS.—Kitsuzo Fuwa (*J. Jap. Cer. Assoc.*, **366**, 80, 1923). The colouring action of manganese compounds on various glasses was studied. The formula of the standard glass was $R'_2O{\cdot}R''O{\cdot}3SiO_2$; $R'_2O{\cdot}R''O{\cdot}0{\cdot}5B_2O_3{\cdot}3SiO_2$ or $1{\cdot}3R'_2O{\cdot}R''0{\cdot}6SiO_2$ where R′ and R″ represent Na or K and Ca,Mg,Zn,Ba or Pb respectively. The results of 591 meltings with 100-150 g. or 1 kg. batch are given. (i.) Manganese dioxide. According to Meyer and Roetgers, this oxide dissociates into Mn_2O_3 at 530°C. in air. Generally speaking, soda glass has pink shades and is not so clear as potash glass, although these differences disappear at higher intensities. PbO encourages the colouring. It is very likely that MnO_2 is decomposed to $aMn_2O_3+bMnO+cMnO_2$ in the melting. The proportion of these three oxides, and accordingly the colour are affected by the composition of the glass. (ii.) Manganese oxide. This is almost colourless, but yellow or blue glass is obtained when such amounts of MnO are used, which will produce light purple or pink with MnO_2. (iii.) Manganous carbonate. Its action is similar to that of MnO. Thus the pink or purple is not due to MnO, but to higher oxides; probably Mn_2O_3. (iv.) Manganese dioxide and nitrate of potash or soda. These nitrates favour the colouring in most cases. (v.) Manganese dioxide and potassium tartarate. The reducing agent counteracts the dioxide in most glasses. (vi.) Manganese dioxide and arsenious acid. Arsenious acid generally tends to reduce the colouration of MnO_2 markedly. (vii.) Manganese dioxide, arsenious acid and nitrate of potash or soda. The colours seem to be affected by complex reactions which occur in melting. But any MnO_2 remaining in the resulting glass, will produce a brown and Mn_2O_3 a pinkish purple or purple, while MnO has no colouring action.
S. KONDO.

THE COLOURING ACTION OF MOLYBDENUM ON GLASS.—Kitsuzo Fuwa (*J. Jap. Cer. Assoc.*, **367**, 129, 1923). The action of molybdenum as a glass colourant was studied by adding 1·0-7·5% of ammonium molybdate to 20 different glasses with the formulae: $R'_2O.R''O{\cdot}3SiO_2$ and $R'_2O.RO$ $0{\cdot}5B_2O_3.3SiO_2$. Results: (1) Molybdenum causes no particular colouration. (2). Glass with molybdenum was very often opacified by reheating; this property is closely related to its composition. (3). Excess of molybdate to the extent of about 5% collects as white gall on the surface or as grains at the bottom. These are chiefly composed of alkali molybdates. S. KONDO.

THE DETERMINATION OF SULPHATE, CHLORIDE, AND CARBONATE RADICALS CONTAINED IN SODA-LIME GLASSES.—Masao Igawa (*J. Jap. Cer. Assoc.*, **367**, 131, 1923). The author suggests the use of ammonium fluoride, NH_4HF_2, as a decomposition reagent in the determination of sulphuric anhydride, chlorine and carbonic anhydride contained in glasses. (1). Preparation of ammonium fluoride for the determination of sulphuric anhydride. Silicon fluoride obtained by the action of sulphuric acid on ground quartz and ammonium fluoride is introduced into water. After filtering, the solution is treated with an excess of ammonia, filtered through muslin and evaporated to dryness. Ammonium fluoride thus obtained is refined once more by sublimation. (2). Preparation of ammonium fluoride for the determination of chlorine. Ammonium fluoride is purified by treating its solution with silver nitrate. It is then sublimed. (3). Preparation of ammonium fluoride for the determination of carbon dioxide. Ammonium fluoride is dissolved in water and treated with ammonia. The solution is evaporated after filtration. (4). Determination of SO_3. 3 g. of glass are mixed with about 9 g. of ammonium fluoride, and 5-6 cc. of water are added. The mixture is evaporated to dryness, treated with sodium-carbonate solution and filtered. The filtrate is once more evaporated to dryness. It is then extracted with 50% alcohol. The extract is evaporated to dryness, acidifying the solution with oxalic acid. Sulphuric anhydride in the residue is determined with barium chloride, after dissolving it with dilute HCl. (5). Determination of sulphur. Total sulphur is determined as described above, but the sample must be decomposed in the presence of bromine. (6). Determination of Cl. 5 g. of the finely ground sample are mixed with about 15 g. of ammonium fluoride in a platinum dish. The glass is decomposed by adding 30 cc. of water to the dish and heating it at 60°-70°C. Chlorine is determined gravimetrically with silver nitrate, after removing silicic acid with ammonia. (7). Determination of CO_2. 15-20 g. of coarsely ground glass are put in a lead flask and decomposed by 25-20% solution of ammonium fluoride. CO_2 liberated from the glass is absorbed by soda-lime, the apparatus and procedure being exactly like those for determining CO_2 in common carbonates by the Fresenius-Classen method. (8). Examples of analysis. Analyses of Belgian and American glasses are :

No.	Na_2SO_4 (%)	Sulphur in forms other than sulphates, expressed as Na_2SO_4. (%)	NaCl (%)	Na_2CO_3 (%)
1	0·667	0·046	0·095	0·048
2	0·908	0·108	0·071	0·040
3	0·068	0·027	0·154	0·055
4	0·960	0·055	0·151	0·021
5	1·045	0·000	0·066	0·051

S. KONDO.

COLOUR IMPARTED TO GLASS BY CHROMIUM.—Kitsuzo Fuwa (*J. Jap. Cer. Assoc.*, **368**, 192, 1923). The colouring action of chromium on glasses with the formula—$R'_2O.R''O3SiO_2$; $R'_2O.R''O.0{\cdot}5B_2O_3.3SiO_2$; $3R'_2O.R''OSiO_2$ or $R'_2O.B_2O_3.6SiO_2$ is reported. Chromium was introduced in the forms of Cr_2O_3, $K_2Cr_2O_7$ and K_2CrO_4. The influence of potassium nitrate and potassium tartarate on the colour given by Cr_2O_3 was also studied. Conclusions : (1). Generally speaking, chromium compounds impart yellowish green colours to glasses. The composition of the glass affects its shade in yellow ; for instance, 0·05% of Cr_2O_3 introduced in batches as such gives a green to $Na_2O.CaO.0{\cdot}5B_2O_3.3SiO_2$, while $Na_2O.CaO.3SiO_2$ is coloured a light yellowish green. (2). Colours given by $K_2Cr_2O_7$ are richer in yellow than those given by Cr_2O_3, K_2CrO_4 being intermediate in this respect. (3). The

addition of an oxidising agent to a batch containing Cr_2O_3 encourages the yellow tint, while reducing agents reduce it. It may be due to the green colouration of Cr_2O_3 and the yellow of CrO_3, or it may be ascribed to the action of these agents on iron oxides. S. KONDO.

THE COLOUR GIVEN TO GLASS BY VANADIUM.—Kitsuzo Fuwa (*J. Jap. Cer. Assoc.*, **369**, 236, 1923). The effect of the composition of glass on the colour imparted to it by vanadium oxide, V_2O_3, which was added to the batch with or without an oxydising agent (potassium nitrate), a reducing agent (potassium tartarate), or arsenious acid was determined. The basal glass was $R_2O.RO.3SiO_2$ or $R_2O.RO.0{\cdot}5B_2O_3.3SiO_2$. The results may be summarised as follows: (1). Generally speaking, the colour given to glass by vanadium oxide resembles that imparted by Cr_2O_3, though the latter has a stronger yellow tint than the former. (2). The colour is not influenced by the composition of glass. In general, boric acid encourages the colouration. (3). An oxydising agent added to the batch causes a slight increase in yellow, while a reducing agent and arsenious acid tend to act the other way. The Colour of vanadium glass may chiefly be due to V_2O_3, and this may be partly oxidised to V_2O_5 which may be a yellow colourant of glass. (4). V_2O_5 can be used in place of Cr_2O_3, though it is too costly for general use. S. KONDO.

ON TESTING CHEMICAL GLASSES.—Torao Kato (*J. Jap. Cer. Assoc.*, **367**, 138, 1923). Detailed descriptions are given of the existing specifications for glass vessels for use in chemical laboratories. The results of elaborate experiments with beakers and various flasks made by several Japanese manufacturers are then described. The adoption of the following methods in the testing of chemical glasses is proposed. Preliminary treatment: Wash the sample with distilled water after rinsing it well with a solution of potassium bichromate in conc. sulphuric acid. (*A*). Tests for endurance of sudden heating. (1). Heat the vessel to 120°C. at least in an air bath and then immerse it neck foremost in water at 15°. (2). Boil the vessel containing a conc. solution of calcium chloride of sp. gr. 1·33 at 15° for five minutes on an asbestos plate and immerse it in water at 0°. (3). Put the vessel which has been three-quarters filled with paraffin on an asbestos plate heated by a Bunsen burner, remove the heat source, read the temperature, and dip it in water at 15° for a moment. The process should be repeated every 5° till it is cracked. The mean value of about three samples must be reported for temperatures over about 160°. (*B*). Tests for resistance to water and reagents. (1). Water. Boil distilled water in the vessel which is kept three-quarters full, for six hours. Loss in weight should be expressed in mg. per sq. cm. (2). Acid. The vessel three-quarters filled with 12% HCl is kept boiling for three hours. The loss is expressed as described above. Its appearance must be inspected. (3). Alkali. Same as (2), except that 2% solution of NaOH is used as reagent. (*C*). Test for dissolved alkali. The water obtained in the test *B* (1) is tested by rosolic acid for the presence of alkali reaction. Standards. (*A*). Endurance of sudden heating. (1). The neck must remain uncracked. (2). The sample should stand the test. (3). The breaking temp. must be over 140° in beakers and conical flasks, and over 130° in round flasks. (*B*). Resistance to water and reagents. (1). Water. The max. allowable loss is 5 mg. (2). Acid. The max. allowable loss is 5 mg. The testing must cause no change in the appearance. (3). Alkali. The max. allowable loss is 30 mg. The boiling must cause no change in the appearance. (*C*). Dissolved alkali. No alkali must be detected. S. KONDO.

CRACKING AND CORROSION OF GLASS POTS.—Sangoro Takshashi (*J. Jap. Cer. Assoc.*, **367**, 149, 1923). Descriptions or discussions on the destruction of pots due to cracking, the manner, cause and prevention of cracking, and the loss due to corrosion, its manner, cause and prevention, are given with photographs. According to statistics for three years at the Tokio Electric Co., most of the cracks in covered pots grew vertically on the inside. This kind of cracking is probably caused by the side pressure of

molten glass, which favours the growing of minute vertical cracks produced, together with those in other directions, during the period of filling. Sometimes they are cracked in various directions, inside or outside the pot, usually during the period of tempering the pots in the pot-arch, or before filling batch in the placed pots. Pots should be tempered at 1,300°C. at least. Corrosion by the usual batch containing 50% of raw material was far more severe than that by a simple cullet batch, indicating that pots are chiefly corroded by fluxes in the raw materials before complete melting, which takes about ten hours. Iron contained in the batch and pot is detrimental in regard to corrosion, especially for lead glass, because it produces metallic lead and ferrous silicates. Excess of flux in the raw materials, or the use of arsenious acid, sometimes causes honey-combed corrosion. In conclusion, the author recommends the use of porous pots lined with a material which will produce sillimanite on using. S. KONDO.

ON THE THERMAL EXPANSION OF SODA-LEAD GLASS.—Jiro Mori (*J. Jap. Cer. Assoc.*, **368**, 176, 1923). The linear expansion of soda-lead glass, completely free from stress, was determined at 30° and 100°C. The maximum difference between the observed linear expansion and that calculated by the aid of Schott's coefficients, amounted to 12%, while they agreed very well only in glasses whose formulae approximate to $6SiO_2.1PbO.1Na_2O$. The author obtained the following coefficients for linear expansion for lead oxide and soda, taking 0·05, 1·53, 1·53 and 0·45 as those of silica, lime, alumina and magnesia respectively: PbO 0·936 and Na_2O 4·70. The following tables show the chemical compositions and coefficients of linear expansion of glasses used in the experiments.

TABLE 1. ANALYSES OF THE GLASSES.

No.	PbO	Na_2O	Al_2O_3	CaO	MgO	SiO_2
10	44·73	4·61	0·72	0·07	0·05	49·82
8	41·83	5·61	1·23	trace	0·09	51·21
6	39·24	6·90	1·14	0·10	trace	52·61
4	37·45	7·88	0·96	0·10	0·03	53·58
2	36·60	8·27	0·97	0·06	trace	54·10
0	33·96	10·02	1·09	0·08	0·01	54·84
1	31·57	11·35	1·15	0·04	0·02	55·87
3	28·01	12·40	0·98	0·09	trace	58·52
5	24·33	13·83	1·19	0·33	0·02	60·30
7	22·94	14·06	1·15	0·18	trace	61·67
9	16·35	16·34	1·15	0·14	0·07	65·95

TABLE 2. FORMULAE AND LINEAR COEFFICIENTS OF EXPANSION.

No.	Formula	Observed coef.	Calculated coef.	Difference
10	$6SiO_2.1{\cdot}5PbO.0{\cdot}5Na_2O$	666($\times 10^{-8}$)	678($\times 10^{-8}$)	+8($\times 10^{-8}$)
8	,, ,, 1·4 ,, 0·6 ,,	705	704	−1
6	,, ,, 1·3 ,, 0·7 ,,	729	739	+10
4	,, ,, 1·2 ,, 0·8 ,,	761	764	+3
2	,, ,, 1·1 ,, 0·9 ,,	781	776	+5
0	,, ,, 1·0 ,, 1·0 ,,	844	836	−8
1	,, ,, 0·9 ,, 1·1 ,,	880	877	−3
3	,, ,, 0·8 ,, 1·2 ,,	903	892	−11
5	,, ,, 0·7 ,, 1·3 ,,	934	933	−1
7	,, ,, 0·6 ,, 1·4 ,,	929	929	0
9	,, ,, 0·5 ,, 1·5 ,,	966	975	+9

The coefficient is, on the whole, a function of chemical composition. However, as indicated in the latter table, it does not follow the additive law exactly. This fact causes differences which are a little greater than experimental errors. S. KONDO.

COLOUR GIVEN TO GLASS BY ANTIMONY OXIDE.—Kitsuzo Fuwa (*J. Jap. Cer. Assoc.*, **369**, 241, 1923). The colouring action of antimony oxide on glass was studied by introducing 10-30% of Sb_4O_6 to glasses corresponding to: $1{\cdot}3R_2O.RO.6SiO_2$ and $R_2O.B_2O_3.6SiO_2$, with the result that the oxide does not cause any particular colouration, and also that re-heating of glasses, which have high contents of antimony oxide, in a gas-fired kiln, usually produces iridescent effects, light greyish black to black in colour, on their surfaces. S. KONDO.

THE COLOUR GIVEN TO GLASS BY TUNGSTEN.—Kitsuzo Fuwa. (*J. Jap. Cer. Assoc.*, **370**, 302, 1923). The colouring action of sodium paratungstate ($Na_{10}W_{12}O_{41}.28H_2O$), tungsten trioxide and metallic tungsten on glasses with the formulae: $R_2O.RO.3SiO_2$ and $R_2O.RO,0{\cdot}5B_2O_3.3SiO_2$; also the effect of oxydising agents and arsenious acid on the action of the sodium tungstate, were studied. The results of 142 meltings and the effect of reheating these glasses are described. Results: (1). Sodium tungstate or tungsten trioxide mixed in glass-batches produces no particular colour. (2). Metallic tungsten produces very often a yellow or orange in glass. Similar colouration is rarely observed when sodium tungstate or tungsten trioxide is used. Metallic tungsten often gives a grey colour to glass. Melting a batch with metallic tungsten will result in the production of a system such as: $a\mathrm{W}+b\mathrm{WO_3}+c\mathrm{Na_2(K_2)WO_3}+$glass. Presence of the yellow oxide will colour the glass yellowish. Suspension of tungsten or its blue oxide will give a grey to the glass. (3). Sodium tungstate has a tendency to produce an alabaster-effect or opacity, especially in glasses free from boric acid. The tendency is also observable in metallic tungsten and its oxides, though it is very weak. The phenomenon is probably due to a fine suspension of tungsten oxides. (4). Sometimes an excess of tungsten salts, its oxides or metallic tungsten, produces gall on the surface of glass or a massive precipitate at the bottom; these consist of soluble tungstates of alkali metals. (5). Introduction of sodium tungstate accompanied by an oxydising agent or arsenious acid produces no particular colour. (6). Salts or oxides of tungsten can be used as opacifiers, but not as colorants. S. KONDO.

PATENTS.

GLASS BLOWING.—E. H. Lorenz (*Pat. J.*, 1,803, 1923). No. 199,377, May 29, 1923. Description of a press-and-blow machine.

SHEARING GLASS.—R. F. Hall (*Pat. J.*, 1,804, 1923). No. 199,414, Dec. 23, 1921. An arrangement is shown for raising the mould to an intermediate position in which the cut-off is effected.

GLASS BLOWING.—H. T. Davis (*Pat. J.*, 1,804, 1923). No. 199,558, May 4, 1922. A description is given of a porous mould for blowing glassware.

ORNAMENTING GLASS.—J. J. Wilson and W. Wilson (*Pat. J.*, 1,804, 1923). No. 199,623, July 22, 1922. Relates to double transfer processes for decorating the back of glass to show through at the front.

CUTTING GLASS.—Libbey Owens Sheet Glass Co. (*Pat. J.*, 1,804, 1923). No. 199,653, Oct. 10, 1922. An apparatus for scoring and dividing sheet glass is described.

ORNAMENTING GLASS.—G. L. Huysmans (*Pat. J.*, 1,805, 1923). No. 199,802, Nov. 28, 1922. Raised designs can be produced on glass or pottery by applying a plastic composition consisting of finely powdered metals, such as copper, aluminium and magnesium, mixed with an amulsion of calcium carbonate, a thick solution of mucilage, aluminium sulphate, coaltar or drying oil.

DELIVERING MOLTEN METAL.—F. O'Neill (*Pat. J.*, 1,805, 1923). No. 199,805, Mar. 28, 1922. A plunger for use in an automatic feeder is described.

DRAWING SHEET GLASS.—Libbey Owens Sheet Glass Co. (*Pat. J.*, 1,805, 1923). No. 199,881, Apr. 28, 1922. By the process described, the lateral parts of the sheet are guided, on leaving the mass of glass, so as to maintain the edges in a predetermined direction.

HEAT-RESISTING GLASS.—C. J. van Nieuwenburg (*Pat. J.*, 1,805, 1923). No. 200,020, Nov. 1, 1922. Lithium-alumino-silicate, preferably as lepidolite, is added to the ordinary batch, with the addition of zinc oxide or boric acid compounds to promote the melting process. The glass has an increased tensile strength with a resultant increased thermal endurance.

GLASS-REFINING FURNACES.—A. Grauel (*Pat. J.*, 1,808, 1923). No. 200,900, Apr. 19, 1922. Relates to electrode furnace, having a number of inter-connected chambers separated by partition walls.

SHAPING BOTTLE NECKS.—G. E. and H. A. Bateson (*Pat. J.*, 1,808, 1923). No. 201,000, June 16, 1922. A description of a machine is given.

DELIVERING MOLTEN GLASS.—E. O. Hiller (*Pat. J.*, 1,793, 1923). No. 195,927, Oct. 25, 1922. Description of an automatic feeder.

TOUGHENING GLASS.—Corning Glass Works (*Pat. J.*, 1,798, 1923). No. 197,381, Feb. 7, 1922. Glass articles may be cooled rapidly while heated to a point above the annealing temp. of the glass by high velocity air jets directed on the article normal to its surface. A method of carrying out the operation is outlined.

HEAT-ABSORBING GLASS.—Chance Bros., & Co., and A. L. Forster (*Pat. J.*, 1,798, 1923). No. 197,500, Apr. 11, 1922. The proportion of ferrous oxide in the glass is such that the desired absorption and transmission of thermal and luminous radiations are obtained. The ratio of luminous radiation transmitted to thermal radiation absorbed is a maximum in a glass containing about ·01 grams ferrous oxide per sq. cm. of surface. Such glass is suitable for windows, etc., in hot countries.

SEALING ELECTRIC LAMP BULBS; REFINING GLASS.—L. S. Vello (*Pat. J.*, 1,799, 1923). No. 197,693, May 11, 1923. Apparatus is described for exhausting and sealing bulbs made in two parts joined together by a ring of fusible glass, and also for refining the glass of which the ring is made.

CUTTING GLASS TUBES.—Philips' Gloeilampenfabrieken (*Pat. J.*, 1,800, 1923), No. 197,937, May 15, 1923. An apparatus for cutting continuously-fed glass tubes into sections is described.

GLASS-BLOWING MACHINE.—W. D. Morrison (*Pat. J.*, 1,801, 1923). No. 198,485, Mar. 21, 1922. A description of a machine is given.

DELIVERING MOLTEN METAL.—C. H. Rankin (*Pat. J.*, 1,802, 1923). No. 198,952, Sept. 28, 1922. A device is described for feeding molten glass towards and through a discharge orifice.

VI.—CEMENT, CONCRETE, MORTARS, ETC.

THE EFFECT OF HEAT ON GYPSUM.—C. Elliott (*Chem. Tr. J.*, **72**, 725, 1923).

CIMENT FONDU.—(*Chem. Tr. J.*, **72**, 604, 1923). A short account is given of the physical and chemical properties of the new French cement.

PORTLAND-BLAST-FURNACE CEMENT.—(*Chem. Tr. J.*, **72**, 571, 1923). A British standard specification is now in operation for a cement consisting of a mixture of Portland cement, clinker, and not more than 65% of granulated blast-furnace slag.

THE SETTING OF PORTLAND CEMENT.—(*Chem. Tr. J.*, **72**, 454, 1923).

The results are given of an investigation into the cause of changes in the setting-time of Portland cement, carried out by the British Portland Cement Research Association. The effects of (1) storage out of contact with air; (2) exposure to gases; (3) additions of salts; and (4) crystallised water in salts, are indicated.

REAGENTS USED IN ETCHING CEMENT CLINKER FOR THE EXAMINATION OF ITS MICROSTRUCTURE. No. 3 of "The microscopic study of cement clinker." Takehiko Hattori. (*Report of the Industrial Department, Central Research Laboratory, Government of Formosa* – **1**, 1, 1922). It is a well-known fact that thin sections of clinker cannot easily be prepared, owing to its porous and friable nature. The method usually employed consists in polishing a single surface of the specimen, developing the structure by etching with a suitable reagent, and examining under vertical illumination. Water and a dilute solution of HCl in alcohol have been recommended as the reagents. The author has tried other reagents for the purpose. Generally speaking, the sections of Portland cement clinker consist of crystalline grains (alite) and filling substances. The filling substances do not react uniformly with etching agents. Some portions of the filling substances in polished but unetched sections look grey under vertical illumination and are easily etched, while other portions are white and resist reagents better than the former. Eutectic structure is frequently observed in the filling substances. There are also grains which resemble alite but show different resistance to reagents. A well-fired shaft-kiln was used in the experiments. The results are summarized in the following table:

Reagents	Substances which have been etched in one minute	Substances which have been etched in 3-5 minutes	Substances which have been etched in 10-30 minutes
Water	Grey substance (slightly)	Grey substance	Grey substance; Crystalline grains
0·2% solution of cane sugar	Grey subs.	Grey subs.; crystalline grains (slightly)	Grey subs.; crystalline grains
10% sol. of cane sugar	Grey subs.; crys. grains (slightly)	Grey subs.; crys. grains (slightly)	Grey subs.; crys. grains
1% sol. of am. oxalate	Crys. grains	Crys. grains	Grey subs.; crys. grains
2% sol. of sod. sulphate	Grey subs.	Grey subs.; crys. grains	Grey subs.; crys. grains
0·5% sol. of boric acid	Crys. grains	Crys. grains (severely)	Crys. grains (severely)
3% sol. of caustic soda	Grey subs.	Grey subs.	Grey subs.; crys. grains (slightly)
3% sol. of am. sulphate	Crys. grains	Crys. grains	Crys. grains
0·5% sol. of calcium chloride	Grey subs.	Grey subs.	Grey subs.; crys. grains (slightly)
0·5% sol. of alum	Grey subs.; crys. grains (severely)	Grey subs. (severely; crys. grains (severely)	Grey subs. (sev'ly) crys. grains (sev'ly)
4% sol. of sod. chloride	Grey subs.	Grey Subs.	Grey subs.; crys. grains

The white substance was not attacked by water even when the section was immersed for 24 hours in it. A solution of cane sugar retards the setting of the cement when its concentration is weaker than 0·5%, while it accelerates the setting when its concentration is stronger than 1%. When sections were treated with the 0·2% solution for 5 minutes the eutectic structure in the grey substance was distinctly developed as white spots. When sections were treated with the 10% solution for 5 minutes grains resembling the crystalline ones appeared. The author considers them to be free lime. In conclusion, the author recommends the use of am.oxalate or am.sulphate for examining the distribution of alite crystals and the use of calcium chloride or cane sugar for the observation of the grey substance. S. KONDO.

THE EFFECT OF AERATION ON THE PROPERTIES OF PORTLAND CEMENT.—Takehiko Hattori. (*Report of the Industrial Department, Central Research Laboratory, Government of Formosa*, **1**, 7, 1922). The influence of aeration of four commercial Portland cements upon their various properties is described. The aeration was effected by spreading the cement in a shallow box and turning it over once a day. (1). *Loss on ignition.* This increases with the time of aeration. One cement showed 0·64%, 1·72%, 3·90%, 5·74%, 8·23% and 10·74% ignition-loss at the end of 0, 1, 4, 8, 13 and 20 weeks respectively. (2). *Constancy of volume.* The linear expansion of test pieces made of cement with Le Chatelier's mould was measured by immersing them immediately in water. The average increase in length after 24 hours was as follows :

Time of aeration	0	3 days	2 weeks	4 weeks	8 weeks	20 weeks
Expansion in mm.	0·7	0·3	0.6	0·3	0·1	0·1

(3). *Time of setting.* Aeration first retards the setting, then accelerates it and a further aeration retards it again. (4). *Strength.* In general, the strength of a cement is decreased by aeration. Tables and curves showing heat evolved in setting are also shown. The author discusses the influence of free lime on various properties of cements. S. KONDO.

REPORT ON TESTS WITH VOLCANIC ASH OF FORMOSA.—K. Fujisawa and K. Sai. (*Report of the Industrial Department, Central Research Laboratory, Government of Formosa*, **1**, 25, 1922). In Formosa, the demand for volcanic ash for marine construction has steadily increased. It is chiefly imported from the Karatsu district. The authors have tested the native volcanic ash which they found in the north end of the Island. The chemical compositions are :

District	Loss on ignition	Silica	Soluble silica	Ferric oxide	Alumina	Lime	Magnesia	Sulphuric anhydride
Hokutosho	16·46	43·63	29·83	12·29	25·48	0·62	0·60	0·19
,,	17·07	42·10	30·47	13·35	26·30	0·52	0·34	trace
Karatsu ..	17·09	37·08	27·08	16·36	25·60	trace	1·90	trace

Tests on the physical properties have shown that the Formosan products are as good as those of Karatsu. Mortars composed of Portland cement 70% and volcanic ash 30%, or Portland cement 70%, volcanic ash 21% and lime 9% by weight, complete their setting quicker than the neat cement mortar. The Formosan products are more active in this respect than those of Karatsu. S. KONDO.

MEREN SAND FOR PORTLAND CEMENT TESTING.—K. Fujisawa. (*Report of the Industrial Department, Central Research Laboratory, Government of Formosa*, **1**, 37, 1922). The standard sand of the Japanese Portland

cement specification is made by sifting ground quartz through sieves of 64, 144 and 225 mesh to the sq. cm., the gauges of the wires being 0·4, 0·3 and 0·2 mm. respectively, and then mixing equal parts of the residues left on the 144 and 225 meshes. Since its supply is short for the time being, the author proposes the adoption of the Meren sand as the local standard in Formosa. The tensile strength of mortar with the native sand is generally 10-20% lower than that with artificial sand, while for crushing strength the comparison is exactly reversed. S. KONDO.

SLAG CEMENT AND DOLOMITIC CEMENT.—Saburo Kimura (*J. Jap. Cer. Ass.*, 364, 595-608 1923). (i.) Slag cement. Tensile strength of numerous mortars composed of granulated blast-furnace slag of the Anzan Iron Works or the Honkeiko Iron Works, Portland or natural cement, slaked lime and sand have been studied. To cite some of the results on the Anzan slag which was ground to pass through a sieve with 2,500 meshes per sq. cm. and contained 36·97 soluble silica, 1·08 insoluble matter, 11·86 alumina, 0·40 ferric oxide, 44·83 lime, 2·52 magnesite, 0·66 sulphuric anhydride and 1·64 sulphur, we have :

Proportion in weight.				Tensile strength, kg./sq. cm.			
Slag	Portland cement.	Sand (%)	Seawater	7 days	28 days	3 months	6 months
—	1·0	3·0	8·3	15·3	20·0	23·4	25·8
0·9	0·1	3·0	8·8	8·0	22·4	24·5	26·0
0·8	0·2	3·0	8·3	8·4	22·5	25·8	25·0

Slag accelerates setting of Portland cement, thus :

Proportion in weight.			Setting time, in hour, and minutes.		
Slag	Portland cement	Fresh water (%)	Temp. in C.	Initial set	Final set
—	1·0	25·0	20·5°	6·04	9·52
0·7	0·3	43·0	20·5	1·12	6·03

(ii.). Dolomitic cement. Tensile strength of dolomitic cements which were prepared by calcining four kinds of Manchurian dolomite for several hours at 600°-700°C. and then by grinding them to pass through a 900 mesh sieve was tested. The strength and hydraulicity increase with its content in soluble silica. Some of the results obtained with a dolomite containing 19·14 soluble silica, 0·66 insoluble matter, 1·10 alumina and ferric oxide, 27·74 lime, 22·41 magnesia and 28·34 loss on ignition are as follows :

Proportion in weight.				Tensile strength, kg./sq. cm.		
Calcined dolomite	Portland cement	Calcined pegmatite	Anzan slag	Sand	14 days	28 days
—	1·0	—	—	3·0	17·9	25·0
1·0	—	—	—	3·0	6·9	15·0
0·9	0·1	—	—	3·0	6·9	11·9
0·9	—	0·1	—	3·0	8·1	12·5
0·9	—	—	0·1	3·0	15·0	19·4

Thus, dolomitic cement with small additions of blast-furnace slag is a good hydraulic cement and can be used as a substitute for white Portland cement, as it can be prepared nearly pure-white. S. KONDO.

ON THE CRUSHING STRENGTH OF CONCRETE AND THE PROPORTION OF ITS MATERIALS.—Shukichi Nagaya (*J. Jap. Cer. Assoc.*, **366,** 75, 1923). The paper may be regarded as a summary of the author's reports which have been published since 1918. (1). Amount of water. (*a*) The amount of water used in concrete must be expressed as a percentage of the total amount of cement and sand. (*b*) Excess of water reduces the crushing strength ; the decrease percentage volume of water is about 100 lbs.

per sq. in. for Portland-cement-sand-gravel concretes. (*c*) Excess of water is the most usual cause of air cracking. The author observed cracking due to blowing of cement in concrete construction only once in his career. (*d*) The effect of excessive water is more serious in concretes with volcanic ashes or diatomaceous earth, as they absorb much water. (2). Proportion of sand. The crushing strength of concrete depends chiefly on the nature of its mortar ; the effect of varying the proportion of gravel is very slight within a wide range. Concrete with 1 : 3 mortar can never be as strong as that with 1 : 2 mortar. (3). Ageing. Concrete with a cement which has been stored for 6 months is at least 10-20% weaker than that with fresh. Failures in concrete structures are frequently due to an old cement which causes incomplete mixing of the materials and also makes the concrete porous. The author suggests the use of Portland cement without testing. S. KONDO.

PATENTS

CEMENT MANUFACTURE.—T. Rigby (*Pat. J.*, 1,803, 1923). No. 199,056, Dec. 19, 1921. Apparatus is described by means of which cement materials in the form of slurry or powder are dried before admission to the kiln by being dispersed and carried in suspension in a stream of hot gases from the kiln.

PROCESS FOR MAKING CEMENTS.—O. Nickel and R. Markwitz (*Pat. J.*, 1,804, 1923). No. 199, 575, May 25, 1922. The ingredients—quicklime added to siliceous materials such as slags, pumice, trass, etc.—are mixed perfectly dry and ground to the fineness of cement. 1-5% of gypsum may be added.

IMPROVED CEMENT.—J. Sperni (*Pat. J.*, 1,806, 1923). No. 200,311, May 30, 1922. To improve the adhesive and setting properties of cement comprising burnt magnesite and unburnt clay, zinc oxide and one or more of the oxides of manganese, particularly the dioxide, are added to the mixture.

CONCRETE MIXERS.—G. W. Adams (*Pat. J.*, 1,807, 1923). No. 200,498, June 21, 1923. A description is given of an oscillating batch mixer.

WATER-PROOFING CONCRETE.—F. Hartgrove (*Pat. J.*, 1,807, 1923). No. 200,564, Apr. 10, 1922). A suggested dressing consists of copperas, glue and water.

HYDRAULIC CEMENT.—E. Grothe (*Pat. J.*, 1,799, 1923). No. 197,702, May 15, 1923. The cement consists of a finely-divided mixture of foundry slag with ferruginous, siliceous, and alumina, lime-, and magnesia-containing ingredients, the proportions depending upon the composition of the slag.

CONSOLIDATING CONCRETE.—F. G. and E. L. Lynde (*Pat. J.*, 1,799, 1923). No. 197,735, Feb. 17, 1922. A machine for consolidating concrete by vibration is described.

MOULDING CONCRETE PIPES.—B. Heffer (*Pat. J.*, 1,800, 1923). No. 198,161, Apr. 5, 1922. Means are described for withdrawing the cone helically from the pipe, the inner surface of which is smoothed by a trowel carried at the lower end of the core.

MOULDING CONCRETE PIPES.—J. G. Zwicker (*Pat. J.*, 1,802, 1923). No. 198,896, May 22, 1922. Description of apparatus.

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